SCIENTIFIC AMERICAN SUPPLEMENT

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VOLUME LXXX] NUMBER 2072] NEW YORK, SEPTEMBER 18, 1915 [10 CENTS A COPY $5.00 A YEAR

A field telephone station on the battle front on the Aisne, in France.

The Telegraph and Telephone in the German Army

An Elaborate Organization That Has Brought About Great Changes in Maneuvers

WITHOUT the aid of science the huge proportions of the present war would be impossible. It is the irony of our present civilization that the great technical advances of the last decades are being used to their utmost limits to promote the destruction of man by man. Of all the scientific discoveries and inventions turned to the purposes of war probably the most useful are the telegraph and the telephone, by which the headquarters of an army may be connected with its farthest outpost.

History contains many examples of victory won through the speedy arrival of intelligence and of misfortune or defeat arising from the tardy transmission of a command or information. The telegraph, the telephone, or the latest form of electric communication, the wireless, requires fewer minutes, or even moments, of time to convey a report than was needed of hours or days by the former dispatch-rider. So the electric wire may justly be called the nervous system uniting the brain of an army, the headquarters, with all its parts, and these parts again, in all their sections, with one another both in camp and on the field of battle. The German general staff in its "Studies in Military History and Tactics," says: "To-day we consider it positively necessary that the electric wire, either as telegraph or telephone, should follow the commanders and troops into the battle, and that the important part which it has had among us since the war of 1866 as an aid to strategy in controlling large areas should also be developed on the battlefield. The report can be followed by the command and the command by its execution without loss of time."

In 1854 the Prussian Ministry of War made the first German experiments with the use of the telegraph for military purposes, and the men for the new branch of the army were taken from the State telegraph department. In the war waged by Prussia and Austria against Denmark in 1864 the military telegraph was employed for the first time by the Germans. One result was that in ten or twelve minutes after the storming of the fortifications of Düppel in Schleswig the news of the victory reached Berlin and Vienna, a speed of military communication before unheard of on the continent. Prussia made much greater use of the military telegraph in the war of 1866 against Austria, when for the first time reports were made and commands directing the movements of troops were given by telegraph on the field of battle. The new military auxiliary was employed on a large scale in the war of 1870-71 between Germany and France.

As many of the German troops, both officers and privates, were unaccustomed to a military telegraph and had but little understanding of its use, the telegraph division was often baffled in its work by the men of its own army. The transport of materials for the lines was delayed, necessary help was not given, the lines were damaged, and the poles were at times taken for bivouac fires. Once during the siege of Paris, when a double telegraph line was to be laid around the city, a large amount of steel wire intended for this purpose disappeared, and it was found that it had been taken by an artillery company to bind fascines for earthworks. The telegraphers were not at this date organized as an integral branch of the army, but were simply an auxiliary body drawn from the officials of the State telegraph department, just as at the present time the field post office of the Germans is served by postal clerks. It was evident that the field telegraph should be managed by soldiers' not civilians, and in 1877 a field telegraph troop was formed as a branch of the engineers corps. In 1899 this troop was developed into an independent telegraph corps, which at present consists of four battalions with headquarters at Berlin, Frankfort-on-the-Oder, Koblenz, and Karlsruhe.

The telephone was taken into German army use

(*Continued on page 181*)

Some Aspects of the Atomic Theory*

Distinctions Between Molecules and Atoms and Results Derived Therefrom

By Prof. Frederick Soddy, M.A., F.R.S., University, Aberdeen

EITHER matter must occupy space continuously or it must exist in the form of discrete particles. The historical origin of the Atomic Theory of matter is to be found in the choice between the two possible answers to these mutually exclusive alternatives. But this is little more its real origin than is Prout's celebrated guess that all elements are built up of hydrogen the real origin of our present far-reaching conclusions as to the structure of atoms. The true origin of the Atomic Theory is recognized universally to have been during the first decade of the last century in Dalton's discovery of the simple laws of chemical combination, though, even to the discoverer himself, the laws of gaseous behavior, upon which later the totally distinct but inextricably interwoven Molecular Theory was to be based, undoubtedly played a part in directing the interpretation he put upon these laws.

Henceforth science was to deal no longer with atoms as the end results of a purely mental process of the subdivision of matter, a process which must of necessity have an end if matter does not occupy space continuously, but with atoms of definite mass, determinable simply and exactly relatively, that is, the mass of any one kind of atom in terms of that of any other. Absolutely, of course, these masses have only been precisely determined in the present century. In the words of Sir J. J. Thomson in his recent Romanes Lecture, "Dalton traced the atoms of the different elements in all their migrations from one compound to another by means of their weight; this was a quality they could neither change nor disguise; until quite recently, however, this was about the only quality of the atom of which this could be said." And, it may be added, it was the difference of the weights of atoms of different elements which made the test of value. The long and now admittedly mistaken efforts on the part of what may be termed the thermodynamical school of physical chemists, especially in Germany, to dispense entirely with atomistic conceptions of matter as unnecessary and unproved speculations, always failed to render intelligible the simple laws of chemical combination for which that theory had primarily been created to account. Of chemical origin, its development proper proceeded almost entirely along chemical lines, from the recognition and differentiation of the various kinds of atoms by their weights, to the architecture of complex substances, the number and relative arrangements of the atoms therein, the manner in which they were held together by units of combining power or valency, and to the beautiful space chemistry of the particular varieties of complexes, in which the same atoms may be grouped in two ways absolutely identical on any two-dimensional representation, but in space of three dimensions having the relations to one another of an object to its mirror image. But, although this is the real and only Atomic Theory, it is not the Atomic Theory about which much, perhaps most, has been said and written.

Like the Atomic Theory, the Molecular Theory, which in the past has so often usurped its name, originated in the laws of chemical combination, for the one special case of gases. Gay Lussac's law of combining volumes led Amedeo Avogadro to his famous generalization that equal volumes of all gases, under the same condition of temperature and pressure, contain the same number of *molecules*. It is not a general theory, and indeed we know now cannot apply to some states of matter, though the labors of van't Hoff and succeeding physical chemists of the present era have extended it to the *interior* of liquids with suitable important and extensive modifications. But, quite apart from this, the conception of the molecule is a distinct and independent development of mathematical and experimental physics.

The molecule is not the atom, though in certain special and rather exceptional cases, that of the monatomic gases such as helium and mercury vapor, it happens that the same particle is both the atom and the molecule of the element in question. This one case, which also includes that of the vapors of most metallic elements, when these are gasified at sufficiently high temperature and often when they are dissolved in mercury to form liquid amalgams, furnishes a common point of contact between conceptions which are by their nature and origin very largely distinct.

The Molecular Theory of the physicist, as it now appears, involves nothing of the conception of ultimateness implied in the Atomic Theory. It is based on underlying principles which apply to discrete freely moving particles in general, be they molecules in the ordinary chemical sense or microscopically visible masses, so long as they are free to move about as individuals, as in a gaseous or fluid medium, or even, possibly, in free space, as in a nebula. It was something of a lucky, if confusing, accident that in the simple gases on which Gay Lussac experimented and Avogadro theorized, the molecules are composed of so few, often only two, individual atoms, and that since then even certain monatomic molecules should have been found to be capable of existence.

Of course, it may be urged that the conception of ultimateness no longer, with recent acquisitions of knowledge, does apply to the chemist's atom. But it must be understood that the atomic theory of Dalton has always been concerned with the ultimate particles of the elementary substances, rather than with the ultimate particle of matter in general, so that the new knowledge, in fact, involves only confirmation of old ideas. The atom of uranium is still the ultimate particle of the element uranium. Its disintegration during radioactive change into an atom of radium, three atoms of helium, and two electrons, is in no way inconsistent with the statement that the atom of uranium is the ultimate particle of the element uranium. Indeed, such evidence proves positively that no smaller particle of the element uranium than the single Daltonian atom can be or ever will be known. For, could the term atom have any other meaning than this? If the chemist's atom ever had meant the ultimate particle of matter in general without reference to one and one only particular element, how could it ever have been applied except to the one kind of atom, or one kind of matter, hydrogen, the lightest particle of matter then and still known to science?

It is only comparatively recently with the study of radio-active changes, and the recognition of the profound difference between, for example, the disintegration of a radium atom and the decomposition of a water molecule, that the true conception of the atom as distinct from that of the molecule has become at all general. One would search in vain for any such distinction in, for example, Sir Arthur Rucker's Presidential address on the "Atomic Theory" to the British Association in Glasgow in 1901, or in Clerk Maxwell's earlier articles on the same subject.

Two recent developments have gone to make clearer than ever before the essential difference between the chemist's atom and the physicist's molecule, and also the artificialities that have crept alike into chemical and physical science by the unconscious effort to give to the molecule the generality of application which, in fact, applies only to the atom. In the first place, Perrin's successful application of Avogadro's law to microscopic particles of solids, such as gamboge, suspended in liquids, particles which contain probably billions of molecules of gamboge, in the ordinary chemical sense of the word, is a striking proof that no conception whatever of ultimateness enters into the molecular theory. The size of the particle is of no significance. The sole exact definition of a molecule in the physical sense is that it is a separate particle capable of free and unhampered, or better unanchored, movement, in which movement it is subject to free and unceasing interchange of kinetic energy by collision with other similar freely moving particles. Under such conditions of free motion and mutual collision with interchange of kinetic energy the average amount of kinetic energy of translation which each molecule secures is the same for all molecules independently of their mass, and is simply proportional to the absolute temperature. The ideal gas laws, pv = constant, or $pv = RT$, on which the kinetic theory of gases has been founded, are expressions of the foregoing generalization, the product pv being a measure of energy, which is proportional to the kinetic energy of translation of the individual particles or molecules of the gas, and quite irrespective of the nature of the gas or whether its molecules are light or heavy.

The molecule, unlike the atom, is thus not distinguished by its mass, but by the fact that, independent of its mass, it possesses a definite kinetic energy of translation or sensible heat energy at any definite temperature. This test, as Avogadro first accomplished, enables us to determine the mass and therefore the number of atoms in the molecule, to distinguish the lighter from the heavier and to select those which are ultimate particles in the chemical sense of being the smallest particle of the compound which can exist and which if further subdivided will give rise to new substances different in properties from the original. This process of selection, and the fact that of all the molecules containing any one element, some one or more are always found which contain but one atom of that element, represent the invaluable use chemists have made of the molecular theory in their determination of relative atomic weights.

But the molecular theory applies to any size of particle of any complexity. It is limited only by the condition of free interchange of kinetic energy of translation. The quantum of kinetic energy of translation which each molecule possesses at a definite temperature being fixed, the velocity of translation is inversely proportional to the square root of its mass. This velocity—in the case of hydrogen at ordinary temperature rather more than a mile a second—is in the case of fine microscopic particles still great enough to endow them with the most animated Brownian movement, while in the case of particles large enough to be perceived by a simple lens, it is still appreciable. Beyond this it becomes inappreciable to measurement. It is this, and only this cause which limits the further application of the gas laws on which the molecular theory is based to suspensions of particles large enough individually to be seen by the naked eye. But in imagination it may be extended to a collection of billiard balls floating in a liquid of equal specific gravity, each one of which would be found to be in perpetual Brownian motion on the average with the same amount of kinetic energy as that possessed by a hydrogen molecule at the same temperature, were it not for the fact that the velocity of so great a mass corresponding to this minute quantum of kinetic energy is altogether inappreciable by experiment.

When we contrast with such a conception of a molecule that usually entertained by the chemist, we bring in at once the conception of ultimateness derived from the Atomic Theory. The chemist's molecule is a conception independent of the dynamical law of the equipartition of energy on which the physical molecular theory is based. It stands in the same relation to compound substances as the atom does to elementary substances, and is the ultimate particle of such a compound substance, or the particle than which nothing smaller can exist, exhibiting unchanged the properties of the substance. True, the conception of compounds must be extended to include not only compounds of atoms of different elements, but also compounds of atoms of the same element. To the chemist oxygen and ozone are such compounds, elementary oxygen being oxygen in the special so-called "nascent" condition.

In general, the chemist usually has in mind the molecule with the fewest number of atoms to represent the composition and chemical properties of the compound with which he deals. Such a molecule may or may not, in fact, exist, or it may exist only over a very limited range of physical conditions far removed from those for which his other knowledge of the compound has been derived. But however artificial or special the conditions under which the molecular weight has been determined, the tendency is irresistible to look upon such molecules as having a real general existence. In similar way the physicist extends his molecular conceptions derived from the study of liquids and gases to matter in general.

It is interesting, therefore, to note that the molecular conception, either as a physical or chemical unit, fails completely in the case of crystalline solids. This, the second advance referred to previously, follows from the recent application of the X-rays to crystalline structure by Prof. Bragg and his son, who have shown that any atom of chlorine in the interior of a rock-salt crystal, for example, is fixed in space symmetrically with reference to several sodium atoms around it and with equal justice may claim any one of them as its partner in the hypothetical molecule NaCl. It seems, therefore, that molecules cannot really exist in crystalline solids. Between the crystal as a whole and the single constituent *atoms* of which it is composed there are no intermediate or penultimate particles that can be considered to have a separate existence.

With so much of historical comment on past developments let us refer to a few aspects of more modern advances, some of which are set forth by Sir J. J. Thomson in his recent Romanes Lecture.[1]

The first striking point is the enormous advance in sensitiveness attained when electrified atoms, or gaseous ions, commenced to be studied. "An unelectrified atom is so elusive that unless more than a million million are present we have no means sufficiently sensitive to detect them, or, to put it another way, unless we had a better test for a man than for an unelectrified molecule, we should be unable to find out that the earth was inhabited. . . . A billion unelectrified atoms may escape our observation, whereas a dozen or so electrified ones are detected without difficulty." Owing to the charge

* *Science Progress.*

[1] *The Atomic Theory*, Romanes Lecture, 1914, by Sir J. J. Thomson, O.M. Oxford: Clarendon Press, 1914.

the ions may be sorted out by suitable application of electric and magnetic forces (positive ray analysis), and we get from a mixed gas a limited number of sharply defined streams. "This shows that all the atoms of an element are alike; this has sometimes been questioned." The possibility that the weights of the several atoms of the same elements may differ by varying small amounts on either side of a mean value, much as the individual velocities of gas molecules differ from the mean velocity according to the kinetic theory, is, of course, old. As we read in another connection, "The statistician is content to know that the average height of male adults is, say 5 feet 6 inches, and their waist measurement 3 feet; but it is evident such knowledge would be a very unsatisfactory equipment for one's tailor." It is interesting to know that the results of the positive ray method of gas analysis give no support to such a view, especially as the older line of argument, derived from the extreme sharpness of the individual lines in the spectrum of an element, must now be reconsidered and probably rejected altogether. Spectroscopic quantities seem to depend on atomic charge and not on atomic mass. But that a totally opposite conclusion in the single case of the element neon has been drawn from the work of Ashton by this method in the Cavendish Laboratory is not referred to, nor is the newer theory of isotopic elements founded on the study of radio-active change. Such elements, so called because they occupy the "same place" in the periodic table, are identical in chemical properties and in such physical properties as do not depend directly on the mass, but they may differ by whole units in atomic weight. The work on radio-active change, which has resulted in much that is really new and important in the Atomic Theory and in knowledge of the structure of the atom, it is scarcely necessary to refer to here in detail, as much of it is contained in the recent discussion at the Royal Society on Atomic Structure (see *Science Progress*, July, 1914, p. 169). As, however, the knowledge of the existence of isotopes brings a new possibility to be taken into account in the discussion of the cause of the variation of a few atomic weights from approximate whole numbers, it may be briefly referred to. In radio-active change two kinds of change are observed. In the one, there is expelled from the disintegrating atom an α-particle, which is an atom of helium that has lost two electrons, in the other a β-particle, which is an electron or unit charge of negative electricity. After the first kind of change, the radio-element changes in chemical nature in a manner corresponding with a shift of two places in the direction of diminishing mass in the periodic table, while after the second kind of change the shift is one place in the opposite direction. Hence, two β-ray changes and one α-ray change, in any order of sequence, result in the radio-element reverting to the same place as at first in the periodic table, and though its atomic mass has been reduced by four units, that of the helium atom expelled, its chemical properties are identical with that of its original parent. It is reasonable to suppose, therefore, that not only the radio-elements but possibly some of the stable elements are mixtures of such "isotopic" elements possessing the same net atomic charge and occupying "the same place" in the periodic table, but differing by whole numbers in atomic weight. From such evidence as this it was first proved for the sequence of the radio-elements that the successive places in the periodic table correspond with unit changes in the atomic charge (now called the atomic number), as suggested by van der Broeck. Subsequently, this was confirmed by Moseley's work on the wave-lengths of Barkla's characteristic X-radiations for all the elements systematically. On Rutherford's theory, the atomic number, or number the place occupies in the sequence of elements—starting with hydrogen as unity, helium, two, and so on—is the positive charge on the nucleus.

The positive ray method and gaseous diffusion methods would be almost the only ones capable of distinguishing a heterogeneity of the kind supposed in the theory of isotopes, and many conclusions can scarcely be profitably discussed until the homogeneity of the elements has been systematically re-examined by one or other of these methods. The researches on the variation of the atomic weight of lead from different radio-active minerals, so far as they have yet been pursued, shows that in the case of this one element, at least, the conclusion drawn from the theory is borne out.

Along these lines, we arrive at the view that the periodic law represents a periodic variation of the properties of elements, not with the atomic mass as first concluded, but with the atomic number or net nuclear charge of the atom. At once there arises the question, what is the relation between atomic weight and atomic charge? The fact that the vast majority of the atomic weights are approximately whole numbers, in terms of oxygen as 16, suggests that unit change of atomic charge is accompanied by a change in mass, approximately some multiple of the hydrogen atom. In α-ray changes at the extreme end of the periodic table, the change of charge is two and the change of mass four, and this holds fairly well in the early, but not in the subsequent, part of the periodic table where the atomic weight is greater than twice the atomic number. Sir J. J. Thomson advances grounds for believing that as far as the first 18 elements, there are in reality two series, one with even and one with odd atomic weights, the members of each series increasing with the common difference four. There are, however, two exceptions—beryllium, which on this scheme should have an atomic weight of 8 instead of 9, and nitrogen, which should be 15 instead of 14. Hydrogen, moreover, does not seem to fit in at all.

With regard to the exceptions from the rule of the atomic weights, being approximate integers, the suggestion is made that the excess or deficiency of mass corresponds with the absorption or liberation of energy in the formation of the element, equivalent to that possessed by the mass gained or lost, moving with the velocity of light. Thus, per 35.5 grammes of chlorine, the half-gramme in excess or deficit of the nearest whole numbers would correspond with 2.25×10^{20} ergs, the amount of energy required to keep the "Mauretania" going at full speed for a week. The enormous amounts of energy liberated from heavy atoms in radio-active changes certainly suggest such a possibility. It is interesting also to recall that the very recent results of Honigschmid on the atomic weights of uranium and radium, 238.15 and 225.95 respectively, make that of the former about 0.2 unit in excess of that of the latter *plus* that of the three helium atoms expelled in the transformation. But it has still to be proved how far the unsuspected existence of isotopic elements may not be accountable for the departure of atomic weights from approximate whole numbers which is found in certain cases.

Dealing with the question of the present possibility of artificial transmutation, one conclusion should be widely noted. The question of artificially disintegrating elements by physical means, such as by the electric discharge in vacuum tubes, freshly raised a short time ago by experiments made by Prof. Collie, has been very widely discussed. The frequent appearance of helium and neon in such experiments has been taken to be evidence of transmutational changes. But Sir J. J. Thomson concludes, "I have never, however, been able to get any evidence that I regard as at all conclusive that the atom of one element could by such means be changed into an atom of a different kind; in other words, that by such means we could produce a transmutation of the elements." The Hon. R. J. Strutt's recent experiments also point in the same direction. On the other side, however, Prof. Collie and his co-workers, who have maintained that the apparently miraculous appearance of helium and neon in vacuum tubes submitted to the electric discharge is not a consequence of faulty experimentation and contamination by air, have recently renewed the discussion in the current number of the *Proceedings of the Royal Society* and reaffirm their view that the phenomenon is inexplicable on ordinary lines.

The ratio of mass to weight being constant, for all elements from the lightest to the heaviest and even for radio-active substances, and the view that, in the formation of elements generally, changes may occur in mass, lead to the conclusion that even in the region of sub-atomic changes mass must be proportional to weight. This, if sound, would be of fundamental importance in the theory of gravitation. But, as regards the electrons, it is unknown whether these possess any weight at all, or whether, as might be expected on one of the electrical theories of gravitation, the weight may be abnormally large in comparison with their mass. It will be realized how far we still are from the profitable discussion of the significance of atomic weights. The difference of 0.2 unit noted between the atomic weight of uranium and that of its products, it seems, may arise in at least three ways: (1) by the loss of energy, as Sir J. J. Thomson suggests; (2) by the two electrons, which the atom loses, being abnormally heavy in regard to their mass; (3) by the existence of stable isotopes of uranium differing in atomic weight. Two such are in fact known, differing in atomic weight by four units, but one is probably present in too small proportion to account for the discrepancy in the atomic weight.

Around the views taken of the electron, the atom of negative electricity divorced from matter, the greatest divergence of opinion will probably be found. It possesses inertia or mass, but it is yet unknown whether it possesses weight and, if so, whether the ratio of mass to weight is the same for electricity as for matter. Can it in any sense be reasonably regarded as one of the primordial atoms of matter out of which Prout, and others who have followed him, regarded all atoms as built up? We read, "Since the electron can be got from all the chemical elements, we may conclude that electrons are a constituent of all the atoms. We have thus made the first step toward a knowledge of the structure of the atom and toward the goal toward which, since the time of Prout, many chemists have been striving, the proof that the atoms of the chemical elements are all built up of simpler atoms—primordial atoms, as they have been called." There has been, of course, abundant evidence ever since the work of Faraday on electrolysis in liquids that electric charges are associated with the atoms of matter, and play a vital part in chemical changes.

The above reasoning might be, and has indeed been mistakenly used to show that hydrogen is a common constituent of all matter, since, whatever the matter you may put into a vacuum tube, hydrogen is always obtained from it by the electric discharge. Yet a billion atoms of hydrogen would be difficult to detect, whereas a dozen or so electrons are ample for detection. The use of these refined experimental methods carries with it the necessity of not seeming to draw such simple conclusions. Not that the conclusion is not probably correct, but the evidence here alleged in its support is worthless.

The withdrawal of an electron from the hydrogen atom results in the well-known hydrogen ion, the material particle which confers upon a whole class of substances the common quality of being acids. The hydrogen ion is at once the simplest atom of matter known, and yet according to present views it does not contain a single electron! The α-particle expelled in radio-active changes is the helium ion, the second simplest atom of matter known, and again it does not contain a single electron. If it were necessary to resuscitate Prout's rather obvious hypothesis as to the constitution of matter it would be less fanciful to start from the evidence of radio-active changes, which, many years ago, showed that the α-particle or helium ion is certainly one such primordial material constituent common to the atoms of all the radio-elements. But to prefer to regard the atom of negative *electricity* as the primordial atom of *matter* seems to be a relic of an earlier confusion between electricity and matter that the facts, if not the language of science, have long outgrown.

One gets into closer touch with reality in the recent determinations of the number of electrons present in the atom and in the conclusion that in each atom this number is approximately one half of the atomic weight. The scattering of X-rays by the electrons in the atom we find likened, in a manner that will be helpful to those unable to follow the reasoning, to the scattering of ordinary light by the molecules of air, which produces the blue of the sky, and like the latter method has been found useful to determine the number of scattering points through which the beam passes. Sir Ernest Rutherford's determination of the value of the positive charge of the central nucleus of the atom by the scattering or deflection of the α-rays confirms the aforementioned result. However, these methods, and also the later and more refined one of Moseley on the precise Atomic Number, are at fault in one not unimportant respect. They can only reveal the outer electrons of the atom. They cannot reveal the electron in a central concentrated nucleus where their charge is merged in that of a superior positive charge.

Of these nuclear electrons, as of so much that is fundamentally new about atomic structure, we have learned only by radio-active change. Their precise number is vague, and, though not necessarily large, they are of interest in that they alone are entitled to be considered primordial constituents of the atom in the Proutian sense. A glass rod is rubbed. Do the atoms of matter therein suffer transmutation? If they do not, how can the electrons which have been removed by the rubbing be regarded as primordial constituents? Again, the hydrogen atom loses its electron and becomes a hydrogen ion. Is this a transmutational change? If not, why speak of the electron in question as a primordial constituent? But in radio-active changes, not only the changes effected by the expulsion of the material α-particles, but also those effected by the expulsion of β-particles, or negative electrons, are equally entitled to be considered transmutational in character. By a β-ray change radium-D, which is the isotope of lead, passes into radium-E, which is the isotope of bismuth, and so on. The example serves to bring out into clearer relief the normal role of the electron, which so far from being a primordial constituent is a partner of the material atom, the loss or gain of which is accompanied by no fundamental change of the atom. But even so, it seems a forced mode of expression to represent even the β-ray electron as a primordial material constituent, especially as the α-particle is such a primordial material constituent which does not contain a single electron.

Calorific Value of Coal.

ALMOST without exception the value of a coal is directly proportional to the quantity of heat which it contains. Yet occasional installations are known where the type of boiler, the setting, draft, grate area, and other factors, may demand certain physical conditions in the fuel that may take precedence even over the actual heat content. But these cases are the exception rather than the rule. It becomes of prime importance, therefore, to have an accurate knowledge of the heat possibilities of a given coal, and, indeed, this is made the principal element in contracting and determining the settlement price for coals marketed on the heat-unit basis.

War and the School

How the Interest of German School Children Is Stimulated

By Our Berlin Correspondent

THIS war presents to the impartial looker-on an endless variety of psychological phenomena, distressing as well as comforting. While the fiercest struggle ever witnessed by humanity opens an abyss between nations so far engaged in friendly intercourse, the bonds uniting the members of the same nation are becoming all the stronger, and all domestic strife, all party spirit seems forgotten. While this strengthening of national feeling has occurred in all belligerent countries, it was nowhere more striking than in Germany, where even in normal times discipline holds undisputed sway, and everybody is wont willingly to submit to the dictates of authority. This cult of discipline, of course, accounts for the wonderful unanimity which alone enabled the nation to carry on a struggle unparalleled in history.

The writer had an opportunity, as it were, to observe this discipline in the making, when some days ago he visited an exposition organized by the Central Institute of Education and Instruction. This unique show, housed in the former Academy of Music, Berlin, in fact illustrates the mutual relations of war and the school and gives an excellent iden of how the German educator acts on the youthful mind, so as to imbue it with the necessity of subordination, how he avails himself of the present war for pedagogic purposes, and how the very children share the enthusiasm that has taken possession of their elders.

In accordance with the programme of the Central Institute, the exposition embraces all classes of schools, from the kindergarten to the high schools, pedagogical institutions and the military preparation of the youth. In inviting the German and Austrian teachers to participate in the exposition, the scope of the latter was described as follows:

1. How can pupils of either sex work immediately for the war?

2. What do pupils of different ages know of the war, its fighting methods, weapons, ships, fortifications, etc.? What is their opinion of the present war, what do they think to be at stake, how should one, according to them, behave towards the enemy, especially when wounded or a prisoner of war, etc.?

Gifts for soldiers.

3. What would seem to be the means of informing pupils as to the war and keeping their interest in present events alive?

4. How can the youth be prepared for military service?

The interest taken by school children in the great events of the times is noted throughout the exposition. In fact, all their thoughts may be said to center round the war. Some very clever war drawings due to pupils of the Fichte College, Berlin, are hung up on the walls at the entrance to the large ground floor hall. How the military authorities do all in their power to promote the teaching of war subjects, is shown by the many interesting exhibits of this hall, where models of Rumpler "Tauben," Albatros biplanes, hydroplanes and radiotelegraphic apparatus are shown. An apparatus intended for educational purposes is the Ball Episcope, which allows pictures printed on opaque paper—magazines, post cards, etc.—to be projected on a screen.

Many educational subjects which could formerly be taught only in a more or less theoretical way, have now found a concrete exponent. In Geometry, for instance, the chief interest is now bestowed on field surveying. Pupils are therefore busily engaged in the making of surveying apparatus, comprising theodolites, sextants, telescopes, distance gages, etc. Models of gas motors, X-ray apparatus and telephones are also seen. The remaining part of the large hall on the ground floor is taken up by pupils' work and educational apparatus for the teaching of physical and natural sciences.

Models of war implements made by pupils.

The large hall on the first floor strikingly illustrates the powerful echo which the events of the present day are finding in the youthful hearts of school children. There is, for instance, a comprehensive collection of war drawings that give a most captivating insight into the infantile soul and its ideas on the world war. To note the keen observation and skilled technique of these youthful artists is a matter of surprise. Much sense of art is evidenced also by the war post cards drawn by high school ("Gynasia") pupils, and a collection of drawings on the subject, "War in the Animal Kingdom," shows that even teaching zoology is made to yield its tribute to the one great theme of the day. The subject matter chosen for the teaching of line drawing comprises field sketches, illustrations of projectiles, their trajectories and effects, and geography now attaches increased importance to map tracing.

The literary products of pupils are none the less striking and instructive than those above outlined. Composition at present finds its favorite subjects in war and many samples of such work are on show. Side by side with them there are, however, found spontaneous products of the youthful soul, letters to the elder comrades in the field, dramas and poems in honor of the war, rhetorical and poetical exercises to the memory of teachers killed on the field of honor and journals of the war kept by pupils. Other collections comprise letters from the front by former pupils, programmes of patriotic festivities, addresses and lectures by teachers, etc.

The fourth point of the programme—military preparation of the youth—is represented most comprehensively by photographs showing the various kinds of exercises: Ordinary gymnastics, military drill, boy scouts' work, war games, etc. Models of trenches, bridges, lookouts, and military equipments and uniforms, pupils' records of distance gaging, map tracing, first assistance practice, and many other related subjects, are likewise on show.

Before leaving this most instructive exposition, we just have a glimpse of the hall arranged as a war library for youthful readers, where books, newspapers, magazines, all given up to the war, are on show. These are completed by war reminiscences, such as French class books, Russian illustrated papers, maps of the Russian General Staff, etc.

All in all, the exposition bears witness to a great revolution in the minds of the new generation, much of which, it is hoped, will disappear when peace is restored, while other things of lasting value may retain their hold on education.

Buying and Selling Ore

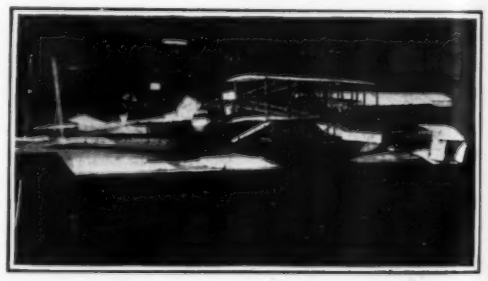
"THE Buying and Selling of Ores and Metallurgical Products" is the title of Technical Paper 83, just published by the Bureau of Mines. Charles H. Fulton, the author, says:

The buying and selling of ores and metallurgical products is a great and highly important business in the United States, and one that concerns not only the miner and the metallurgist, but the industrial world in general. In this paper the attempt is made to outline clearly its underlying principles, the subject matter being based on personal experience and investigation. The author has endeavored to present the material impartially, and for that reason many of the statements and figures regarding metallurgical practice should be taken as illustrative rather than as applying exactly to average operating conditions. Moreover, the statements as to metal prices and trade methods are to be considered as applying to normal business, not to special conditions that have developed as a result of the war in Europe. As regards the style, technical words and phrases have been avoided as much as possible in order to make the paper easily understood by anyone who might be interested.

In estimating the value of an ore or an intermediate metallurgical product (other than a refined metal) the basis used is the price of the refined metal at some principal market center, such as New York, at the time the valuation is made. The average price of all copper for 1913 was 15.5 cents per pound, and for electrolytic copper 15.269 cents per pound. The prices for other metals for the year 1914 were as follows: Lead, 3.862 cents per pound; spelter, 5.213 cents per pound; silver, 54.811 cents per troy ounce. Gold has the standard value, established by law, of $20.67 per troy ounce.

If the metal contents, in pounds for the base metals and in troy ounces for the precious metals, per avoirdupois ton be multiplied by the prevailing price of the refined metals, the sum of the products will be the gross value of the ore.

There is, however, a wide difference between the gross and the net value of a ton of ore. From the gross value must be deducted, first, the total cost of mining the ore, and then the total cost or charge for treatment, which includes some or all of the following items: Freight to treatment plant, milling or smelting charge, charge to compensate for losses of metal in treatment, charge for penalties imposed on undesirable constituents in the ore, charge for freight to refining center, charge for refining the metal, charge to cover the selling costs of the refined metal. Which of these charges are imposed and what the amount of each charge is depend



Aeroplane models at "School and War Exposition."

on the ore, the method of treatment, and the number of firms that handle the ore and metals in the process from ore to refined metal.

The types of companies that handle ores and metallurgical products may be classified as follows:

1. Mining and smelting companies or mining and milling companies, which control all the operations from the mining of the ore to the production and selling of the finished metal.

2. Mining companies, which mine and sell ore on certain schedules to smelting or milling companies.

3. Custom smelters or mills which purchase ores and also operate refineries and produce refined metals or sell intermediate metallurgical products to refineries.

Concerns of type 3 may control mines that furnish a part of their ore supply.

4. Refining companies, which purchase metallurgical products, such as matte, and crude metals, and some ores, and produce refined metals.

5. Selling agencies, which place the refined metals on the market.

It is apparent that an ore or the products derived from it may go through many hands before the finished metal reaches the market, and that metallurgical business may be complex. In this report the essentials of the commercial side of metallurgical work are discussed in some detail.

A field telephone station.

Telegraph squad stringing lines.

Testing a field line.

The Telegraph and Telephone in the German Army

(Continued from first page)

very soon after its appearance, and in 1905 separate companies were formed for the wireless telegraph. In the days of peace before the present struggle began the sections of the telegraph corps were drilled in the practical tasks which would arise in war, building and working telegraph lines under the conditions of a state of war, which are very different from those of peace. They shared naturally in the annual maneuvers where their practise work was put to the test.

Last summer, as the signs of coming trouble increased, both the telegraph and telephone of civil life were kept busy by diplomats who sought to dispel the dangers of war, and when their efforts failed the outbreak of hostilities was announced in a few minutes to all quarters of the globe. Hundreds of thousands, even millions of official telegrams concerning mobilization, were sent in Germany in those days, says Th. Wolff in an interesting sketch in the German journal, *Umschau*, on the use of the telegraph and telephone in the German army. In those days private telegrams lay in piles unsent in the telegraph offices, and letters, although much delayed, actually reached their destinations far sooner. The overworked telegraph officials had barely time to take even a small amount of food, and toiled with overstrained nerves early and late. When the army set out on the march the imperial telegraph was used until foreign soil was reached, then the telegraph division attached to the cavalry took up the task. The cavalry precedes the regular army in order to reconnoiter the positions of the enemy, and has for the sending of its reports a particular kind of telegraph which is independent of the field telegraph proper.

"Every cavalry regiment," says our writer in the *Umschau*, "has a telegraph patrol consisting of noncommissioned officers and men under the command of an officer. The lines, which must be strung very quickly, are not of insulated wire, but consist of thin, uncovered wire called cavalry wire, and are used for induction currents. The transmission is by an apparatus specially made for the cavalry telegraph, and the army telephone. All the equipment is light, simple in care and use, and is carried by the riders in cases on the horses. In putting up the lines a man takes the wire which is rolled upon a spool on a lance, after the one end is secured, and rides off with it, which causes the wire to uncoil and fall to the ground. The first rider is followed by a second, who takes up the wire on a lance with a forked wire end and fastens it to trees, bushes, and when necessary, to stones and similar points of support. In this way one kilometer of line is strung in 10 to 20 minutes, the patrol carrying with it material for 8 kilometers of line. The line leads to the headquarters of the division from which the patrol has been sent, and from this spot can be connected with the next field telegraph station."

Thus the cavalry forms the first telegraphic zone in the field of war; the second consists of the main army behind the patrols. Each army corps is connected by the lines just mentioned with its advance cavalry, and has further telegraphic connection with the headquarters of the army. The putting up and working of such lines is the duty of the field telegraph proper, and for this purpose each army corps has assigned to it a company of the telegraph division, which carries its outfit in light wagons. These lines are insulated cables, and the instruments are very similar to the Morse apparatus. Both telegraphic and telephonic use is made of the field cable. The current is taken from a battery of 12 cells. The cable line, like the cavalry line, is fastened to trees, walls and the like supports, or when these fail it is buried underground. The task of those who put up these lines is varied and difficult, for the cable must not only traverse dry land, but must also cross rivers and small lakes, and this under the lack of many of the usual devices for aid. All these lines meet in the field telegraph station, which, when possible, is established in an inclosed space, as a room, barn, or coach house, but when necessary, use is made of a wagon or tent.

The third zone is formed by the telegraphic connection, running from the field telegraph stations, of the army headquarters with the headquarters of the general-in-chief, and also with the military depots. The stations for these lines are the army telegraph centrals, which are equipped very much like the ordinary telegraph station. The usual methods of telegraph-line construction are used here, both the uncovered wire and the insulated cable being employed. Poles about 4 meters long and 5 centimeters thick are used, and the lines often run long distances. The troop consists of officers, under officers, and men, and has heavy trucks to carry its equipment.

"Connected with these centrals as a fourth zone," continues the writer, "are the depot telegraph offices,

Securing a line on trees.

which work in the rear of the army, and the duty of which is to organize and maintain a constant, prompt, and reliable telegraphic connection of the army with the home country. It is one of the duties, further, of these divisions to occupy the field telegraph stations abandoned at the advance of the army, develop them and establish regular telegraphic work in them. The work of the depot telegraph offices is carried on like that of the ordinary telegraph stations, and with the same equipment, consequently the staffs of these stations are made up not of soliders, but of civil officials appointed by the department of imperial telegraphs."

More depends on the electric wire than merely the preparations for military operations. When the hostile armies face each other it is used for directing the battle. Telephone wires connect the different posts and stations of the field of battle and reach from the actual spot chosen for fighting to the most advanced observation posts and the forward firing lines. These advanced lines are equipped with telephones which unroll automatically as the lines go forward. The telephone connection thus made does away with the necessity of reporting through a man who would be exposed to great danger in carrying a dispatch. The intelligence, moreover, is more quickly and reliably conveyed. Another most important use of the telephone in a battle is in aiding the artillery, which nowadays is generally hidden behind rising ground, a wood, buildings, and the like, and consequently is fired indirectly, without the artillerymen being able to see the mark. An observer watches in an advanced post, which is united with the battery by telephone, and reports the position of the enemy, the effect of the shorts fired, and the changes necessary in the aim. In this way the battery is better protected from hostile fire than when used in direct firing in the open. The battery is also connected by telephone with the commander of the battalion, and the latter with the commander of the regiment. The trackways on which the heavy guns are carried to their positions has also telephonic equipment. As the roaring of cannon makes speech difficult the foot artillery is provided with a special apparatus consisting of telephone, microphone, and mouthpiece, which has proved effective.

The telephone is also used for the trains of siege guns managed by the engineers, and for the field railways which are under the direction of the railway corps. In addition, the wireless telegraph has become an important means of communication in war, especially for the navy.

The present war, says our writer, brings into clearer view the great changes produced in the strategy and tactics of war by the use of the electric wire. The telegraph has made possible the spreading of the divisions of an army over a much greater area than formerly, when a close formation had to be observed to insure speedy warning of danger. This close contact of large bodies of troops in former days often interfered with freedom of movement, increased the difficulties of the commissariat and endangered health. The strategy made possible by the telegraph is best summed up in the words of von Moltke, "to march separately and strike collectively." It has given to the entire intelligence and dispatch system a speed and reliability before unknown, and has reduced to a minimum the belated appearance of expected troops. It has, therefore, been rightly named "the guarantee of punctuality in war."

When the armies once more lay down their weapons the telegraph which was the first to proclaim the outbreak of hostilities, will also be the first to make known the era of peace.

Some few particulars of how the telephone is worked by one of the German armies (that of the Crown Prince of Bavaria) may be of interest. The main exchange is installed in a private house, which, besides several large rooms, contains a number of smaller ones, which are used as telephone boxes. The exchange was completed in the course of three weeks by 300 engineers (soldiers), and has ninety-five direct lines, of an aggregate length of 1,200 kilometers. It was no easy task, as most of the material used was French, and had to be brought together from different towns and adjusted to German requirements. From the exchange five direct lines proceed to each army corps, and from the exchange of each army corps at least two lines go to each division, and from here again lines proceed to the brigades and the regiments. The final lines lead to the trenches, where each battalion, and, in many cases, each company, has its own telephone. In addition, there are special lines between the artillery positions, and from these to the posts of observation. From the main exchange these further proceed in direct lines to the armies, positioned on the sides, and two lines to the headquarters, apart from direct telephone connection from the one army corps to the other. Other lines at the back are connected with the national telephone system. The main exchange alone has to get through several thousand conversations per day. The working of this telephone system is often impeded by hostile artillery fire and other causes, and for safety's sake the sub-stations are generally located in deep cellars. The discovery and repair of interruptions often have to be undertaken under hostile fire. In addition to the telephone, there is also a fairly comprehensive telegraph service, but the telephone is of much more importance,

Measurement of the Distances of the Stars—II*

A Review of Early Efforts and a Discussion of Modern Methods

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2071, Page 163, September 11, 1915

IN the 'eighties, progress became more rapid. Gill, the Astronomer Royal for the Cape, in conjunction with a young American astronomer, Elkin, determined with great accuracy, though with only a small 4-inch heliometer, the distance of nine stars of the southern hemisphere. These stars included a Centauri, and the bright stars Sirius and Canopus. These results were communicated to the Royal Astronomical Society in 1884. The work of Gill and Elkin did not stop there. After some years, a very fine 7-inch heliometer was obtained at the Cape, and with it, between 1888 and 1898, the parallaxes of seventeen stars were determined by Gill and his assistants with very great accuracy. The stars observed at the Cape consisted of the brightest stars of the southern hemisphere, and of the stars with the greatest proper-motions. The results were remarkable. The stars with large proper-motions were nearly always comparatively near—say within one million times the sun's distance. On the other hand, some of the very brightest stars, particularly Canopus, the brightest star in the sky after Sirius, were at vastly greater distances.

Meanwhile, Elkin, who had been appointed director of the Yale Observatory, in 1884, carried out with a 6-inch heliometer, between the years 1885 and 1892, a determination of the distances of the ten brightest stars of the northern hemisphere. After these were finished the Yale observers, Elkin, Chase and Smith, embarked on the ambitious programme of the determination of the distances of 163 stars of the northern hemisphere which show large proper-motion. They have added forty-one southern stars to these, and thirty-five stars of special interest. The results of all these observations were published in 1912. They have not, in most cases, the high accuracy of the Cape observations, but, nevertheless, are of great accuracy, and appear to be free from any considerable systematic error. A third important series of observations was made by Peter with a 6-inch heliometer at Leipzig. These were commenced about 1890, and continued until the death of Prof. Peter in 1911. The parallaxes of twenty stars were determined with the same high accuracy as the Cape observations.

Observations with the heliometer require both skill and industry. To secure the needful accuracy measures must be made in four different positions of the instrument, so that possible small systematic errors may be eliminated by reversal. Great care is required in the adjustments of the instrument, particularly in the accurate determination of the scale-value at different temperatures. The possibility of obtaining satisfactory results with less labor was considered by Kapteyn, in view of the successful determination of the parallax of Gr. 34 by Auwers. From 1885 to 1887 he made observations with the transit-circle at Leyden of fifteen stars for the purposes of determining parallax. The observation consisted in observing the time when the star the parallax of which was sought and two or three neighboring stars crossed the meridian. Observations are made at the two most favorable epochs—say every night in March, and every night in September—to determine whether the star has changed its position relatively to its neighbors in the interval. The difficulties are twofold. The purely accidental error of observations of transits is considerable as compared with the small quantity which is sought. Besides this, the star of which the parallax is required is probably brighter than the comparison stars, and special precautions are required to guard against personal errors of the observer.

In questions of this kind the only satisfactory way is to judge by the results. From observations made on fifty nights, values of the parallax are obtained not nearly so accurate as the best heliometer observations, but still of considerable accuracy. Finally, the parallaxes of four of the stars which had been previously determined by measures with a heliometer showed satisfactory agreement.

This method has been employed by Jost at Heidelberg, very extensively by Flint, at the Washburn Observatory of the University of Wisconsin, and is now being tried at Cape by Voutê, a pupil of Kapteyn's. It appears to me that this method can never give results of the highest accuracy, but that it may be of use in a preliminary search for stars of large parallax. The argument of the facility of the method compared with the heliometer has, however, lost much of its force; for, as I hope to show next, the highest accuracy attainable with the heliometer can be secured much more easily with a photographic telescope.

* The "Halley Lecture" (slightly abridged) delivered at Oxford by Sir F. W. Dyson, F.R.S., Astronomer Royal, from *Nature*.

The application of photography to the determination of stellar parallax was first made by Pritchard in Oxford between 1887 and 1889. He took a large number of photographs and measured on them the angular distance of the star which he was considering from four of its neighbors. In this way he determined the parallax of five stars. He began this work late in life, and it was left for others to develop the photographic method and find what accuracy could be attained with it. At first sight it seems very easy, but experience shows that there are a number of small errors which can creep in and vitiate the results, unless care is taken to avoid them.

It has gradually become clear that with a few simple precautions and contrivances, a greater accuracy can be reached in the determination of parallax by photography and with much less trouble than by any other method. Between 1895 and 1905, several astronomers succeeded in obtaining from a few plates results as accurate as could be obtained from many nights' observations with the heliometer by the most skilled observers. In the last five years a large number of determinations have been made. In 1910, Schlesinger published the parallaxes of twenty-five stars from photographs taken with the 40-inch refractor of the Yerkes Observatory, and in 1911, Russell published the parallaxes of forty stars from photographs taken by Hinks and himself at Cambridge. The opinion expressed by Gill on these observations (*M. N.*, vol. lxii, p. 325), was that but for the wonderful precision of the Yerkes observations, the Cambridge results would have been regarded as of the highest class. The facility with which the Yerkes results are obtainable is expressed very tersely by Schlesinger—"the number of stellar parallaxes that can be determined per annum, will in the long run be about equal to the number of clear nights available for the work." With the heliometer at least ten times as much time would have been required. During the last year two further instalments of the results of the Yerkes Observatory have been published by Slocum and Mitchell, giving the parallaxes of more than fifty stars. It might be thought that the high accuracy attained by them is largely attributable to the great length of the telescope. From experience at Greenwich, I do not think this is the case, and believe that similar results are obtainable with telescopes of shorter focal length. As several observatories are now occupied with this work, we may expect that the number of stars the distances of which are fairly well known will soon amount to thousands, as compared with three in 1838, about twenty in 1880, about sixty in 1900, and now perhaps, two hundred.

The stars the distances of which have been measured have generally been specially selected on account of their brightness or large proper-motion. Each star has been examined individually. Kapteyn has suggested that instead of examining stars singly in this way, photography gives an opportunity of examining all the stars in a small area of the sky simultaneously, and picking out the near ones. The method has been tried by Kapteyn and others—among them Dr. Rambaut. The idea is very attractive, because it examines the average star and not the bright star or star of larger proper-motion. It is liable, however, to some errors of systematic character, especially as regards stars of different magnitudes. Comparison of the results so obtained with those found otherwise will demonstrate whether these errors can be kept sufficiently small by great care in taking the photographs. Until this is done no opinion can be expressed on the success of this experiment, which is worth careful trial.

The question may be asked: How near must a star be to us for its distance to be measurable? I think we may say ten million times the sun's distance. This corresponds to the small angle 0.02 second for the parallax. If a star's parallax amounts to this, there are, I believe, several observatories where it could be detected with reasonable security, though we shall know more certainly by the comparison of the results of different observations when they accumulate.

You will readily imagine that an accurate knowledge of the distances of many stars will be of great service to astronomy. There are ample data to determine the positions, velocities, luminosities, and masses of many stars if only the distances can be found. Thus we know the distance of Sirius, and we are able to say that it is traveling in a certain direction with a velocity of so many miles per second; that it gives out forty-eight times as much light as the sun, but is only two and a half times as massive. The collection and classification of particulars of this kind is certain to give many interesting and perhaps surprising results. But it is not my purpose to deal with this to-night. The task I set before myself in this lecture was to give an idea of the difficulties which astronomers have gradually surmounted, and the extent to which they have succeeded in measuring the distances of the stars.

Two Historical Notes on Flotation

WITH the rapidly increasing use of the oil-flotation process of concentration, and the consequent investigation of various processes and search of the literature on the subject, it is interesting to note some of the earlier work. It will be found true in many instances that various investigators observed certain effects that are now well known, but which may have been passed over at the time without a full realization of their value and importance.

Flotation by means of a stiff froth produced by violent agitation of an ore pulp to which oil has been added, is now one of the most common forms of the process. An interesting early reference to the froth or foam effect is to be found in the *California Journal of Technology* for November, 1903, in an article by Messrs. W. F. Copeland, Drury Butler and James H. Wise. The authors presented some experiments on the Elmore process of oil concentration, which at that time was comparatively new. After describing their experimental work on a variety of ores, they close the article with this interesting reference:

"*Foam Effect.*—The foam effect is produced by a violent agitation, especially in acid or salt solutions. This throws the oil into a froth, which is heavily charged with air or other gases. This gas, of course, gives a greatly increased buoyant force. The oil in this condition assumes a certain load of mineral and holds it in a very stable condition. The charge does not settle and overload on standing as in the case of the lake effect. The foam effect is best adapted for light, flaky minerals, such as molybedenite."

In contrast to the stiff froth or foam formed by violent agitation, there has come into prominence more recently a process making use of a light and less coherent froth, produced by the introduction of air or gas through a porous medium; so that it enters the pulp in a finely divided condition. This effects a gaseous flotation of mineral particles. The froth thus produced breaks down more readily than some of the stiffer froths produced by violent mechanical agitation, and this feature is an advantage in many respects, particularly when the floated concentrate contains two minerals, say lead and zinc sulphides, which are to be separated on tables.

The principles of this method were described by T. J. Hoover and Minerals Separation, Ltd., when in 1910, they secured British patent No. 10,929, based on this method of flotation. But as far as known they did not secure patent in the United States. A quotation from the specification is instructive.

"According to this invention, the method of introducing air or other gas into an ore pulp for the purpose of effecting flotation of certain particles consists in bringing the ore pulp into contact with a porous medium through which air or other gas is caused to pass. Thus, according to one method, the pulp is introduced into a vessel having one or more porous walls through which air or other gas can be caused to pass.

"The porous media employed according to this invention may consist of plates of porous ceramic material, porous bricks, coke, or felt or other fibrous material suitably supported.

"The gas which is caused to pass through the porous medium into the ore pulp may be air or furnace gases, or it may be a gas produced chemically, such as carbonic acid liberated from a carbonate or the gas may be produced electrolytically, or the gas which is passed through the porous medium may act both as selective agent and as frothing agent; a gas such as formaldehyde or carbon bisulphide vapor can be thus employed. The introduction of the gas through the porous medium may be effected either by pressure or by suction."

Effect of Oxy-Acetylene Welding on Health

ATTENTION is called to the fact that when using the oxy-acetylene flame for welding the temperature is so great as to cause the vaporization of some metals; and as the operator has to hold his head quite close to the work he must necessarily inhale some of these metallic fumes, with possible injury to his health. It is suggested that, as the operator must wear colored goggles in any case to protect his eyes from the intense light, it might be well to combine these in a helmet that would protect his lungs.

The Age of the Earth*

A Defense of Lord Kelvin's Theory and Comment on the Same

By F. A. Lindemann

Some fifty years ago, Kelvin announced that the temperature of the earth could not have been anything like its present value for more than some 20 to 30 million years. This estimate was based upon three independent considerations, namely: the temperature gradient inside the earth's crust, the amount of tidal friction, and the total amount of energy radiated by the sun.

The first of these arguments has been invalidated completely by the discovery of the radio-active elements. The other two arguments are scarcely affected by this event.

The geologists always found some difficulty in compressing the history of the earth, more especially of the sedimentary strata, into the period allowed them by Kelvin. Prof. Harker's presidential address before the Yorkshire Geological Society, seems to show that there is a general impression abroad that Kelvin's estimates have been superseded, and that the discoveries in radio-activity allow one to assume a period of the order of thousands of millions of years since the earth has reached a constant state as regards climate. I should like to be allowed to state as succinctly as possible what difficulties this view entails.

The mean temperature of the earth is about 280 degrees absolute. It, therefore, radiates about 1.7×10^{24} ergs per second into space.

Assuming the latest value $1.92 \frac{\text{cal.}}{\text{cm.}^2\text{min.}}$ for the solar constant, the earth receives 1.72×10^{24} ergs per second from the sun. Therefore, the radiation from the sun just compensates the amount lost by the earth; in other words, the temperature of the earth is determined by the temperature of the sun. The possibility that the earth's temperature might have been maintained by radio-active processes before the sun was incandescent, and that the radio-active substances have died off since then need scarcely be discussed seriously. For quite apart from the well-known sterilizing effects of the rays, any radio-active substances with a sufficiently long life to keep up the temperature of the earth for any considerable length of time would not disappear quickly. Uranium, for instance, only diminishes at the rate of about 1.5 per cent. in 100 million years.

One may conclude, therefore, that the time during which the earth can have existed in its present state cannot be greater than the time since which the effective temperature of the sun has been about 6,000 degrees, its present value. This time cannot exceed about thirty million years. For the sun loses energy at the rate of about $3.8 \times 10^{33} \frac{\text{ergs}}{\text{sec.}}$, and the total energy to be gained by a mass of 1.97×10^{33} gm., contracting to a radius 6.96×10^{10} cm., is 2.2×10^{48} ergs, assuming approximate homogeneity. (Taking the increase in density toward the center into account does not alter these figures much). Now even if one assumes that the whole of this energy was radiated at a rate of about

$$3.8 \times 10^{33} \frac{\text{erg}}{\text{sec}},$$

i. e., at the present rate, it will only last 18.3 million years. But any other supposition, namely, that the sun at one time emitted more or less energy per second, leads to a shorter period for the earth in its present state.

To explain a greater age it was necessary to find other sources of energy, and since neither the heat of chemical combination nor any possible increase in the specific heat was anything like large enough, the heat of radio-active transformations was invoked. This was, perhaps, excusible in the early days before very much was known about the laws governing these processes, but it seems quite inadmissible to-day.

It has been suggested that at the enormous pressure and temperature inside the sun radio-active processes might be modified, and even that ordinary elements might break up. A consideration of the quantitative relations involved shows that this is most unlikely. Though one can scarcely apply ordinary thermodynamics to radio-active processes, one can certainly apply the general rule, which may also be developed from the quantum theory if desired, namely, that a reaction the energy of which is A ergs per molecule is affected chiefly by the collisions of atoms of energy of the order A. Now A is of the order 10^{-5} ergs in radio-active processes, and one can, therefore, only expect the temperature to affect those if an appreciable number of atoms have an amount of energy of this order. The average energy of an atom would be 10^{-5} ergs at about 5.10^{10} degrees. Therefore, even at 500 million degrees only one atom among 10^{40} would be moving fast enough to influence a reaction which liberates 10^{-5} ergs. Obviously, 500 million degrees is quite beyond the bounds of possibility in any part of the sun. One must conclude, therefore, that any process which liberates anything like the requisite energy is unaffected by solar conditions, and takes place at the same rate on the sun as on the earth. Thus, one must fall back upon the ordinary radio-active materials, and as Sir Ernest Rutherford has pointed out, one would only gain a paltry five million years even if the whole sun were composed of uranium. The only way out would seem to be to suppose that the sun was created some 10^9 or 10^{10} years ago out of special radio-active material which produces an enormous amount of energy, and that it has been breaking up ever since. This material does not exist on the earth though, so the earth would have to be the object of a special creation. Such an assumption, of course, can neither be controverted nor even discussed. But, unless some such hypothesis is introduced, i. e., unless the presumably radio-active solar material which liberates a quantity of energy sufficient to keep up the sun's heat for the desired 10^9 or 10^{10} years, is supposed to have been created by some inconceivable force at the epoch at which the sun is supposed to have begun to radiate, this material would have disintegrated long ago. It might be objected that the same holds good of uranium, that the fact that uranium exists in measurable quantities proves that it has not existed for a time great in comparison to 5.10^9 years.

This is doubtless true, but there is no real difficulty about assuming uranium or other radio-active substances to have been produced if one supposes the solar system to have been formed by the collision of two stars.

At the moment of collision the velocity of two stars half the mass of the sun would be

$$\frac{1.15 \times 10^{13}}{\sqrt{r}} \frac{\text{cm.}}{\text{sec.}},$$

r being the distance between the centers of gravity. Suppose they both contained some lead, this would reach a temperature of the order

$$\frac{1.1 \times 10^{20}}{r},$$

i. e., of the order 2.10^9 degrees at the moment of collision. As has been shown above, an appreciable quantity of radio-active material might be formed at such a temperature if some helium were present.

But, of course, the heat used up in forming these substances would cool the rest of the mass: any energy gained in radio-active form would be lost in the form of heat. It could never avail to explain a solar constant such as has been measured for longer than Kelvin's 20 million years. In other words, radio-active substances produced would act only as accumulators of energy, not as primary batteries.

To recapitulate: As Kelvin showed, gravitational energy can only account for 18.3 million years of sunshine at the present rate. Invoking radio-activity as a source of energy implies the assumption that unknown radio-active materials liberating considerably more energy than uranium were created by some unknown agency within a measurable period of time, and that these are now breaking up. This assumption is not necessary to account for the existence of uranium, as it is quite conceivable that a certain amount of radio-active matter might be produced afresh during every stellar collision. The energy of substances formed in this way would not be available to explain a greater amount of energy on the sun as their energy is abstracted from the gravitational energy, and has already been taken into account.

A correspondent of *Nature*, C. E. Stromeyer, sends to that publication the following comment on the above article.

While reading through Dr. F. A. Lindemann's defense of Lord Kelvin's estimate of the age of the earth, I was reminded that in spite of the sympathetic spirit in which he always entered into any discussion, he would never allow the least doubt to be thrown on the correctness of his estimate of the earth's age. Yet it is open to several objections: he assumed that the solidified crust, as it was being formed, would sink toward the center of the earth until it was solid throughout, whereas, there can be no doubt about its core being so heavy that the crust material could not possibly sink. He also assumed a diminishing rate of cooling, whereas, the greater portion of the earth's surface is covered by water, the bottom temperature of which must have been practically constant for millions of years. He also cuts down the temperature in the earth's center from 410,000 deg. Fahr., which it would be, according to his assumption, to 7,000 deg. Fahr.; whereby, the available heat is reduced enormously. However, if radio-active processes can supply the earth's radiation losses, there is no need to deal with the older question.

I notice that Dr. F. A. Lindemann draws the conclusion that the sun's radiation just compensates the amount lost by the earth, but this is not correct. The earth's loss is estimated from the known temperature gradient in the earth's crust; it is a net loss over and above any possible interchange of heat with the sun. Then, also, Dr. Lindemann limits the earth's age by the sun's age, but among the several possible sources of its heat supply he does not even mention the heat-producing power of a meteoric bombardment. Yet, as I have shown in my work, "Unity in Nature," in the chapter on matter (pp. 85–92), it is not at all unlikely in comparatively recent time the sun may have passed through a large cloud of heavy meteoric matter. One effect of a comparatively slight addition of heavy meteoric matter would have been to increase its density from, say, 1.00 to 1.38, and the other effect would have been to raise the sun's surface to such a high temperature that it would have evaporated and formed an atmosphere extending, perhaps, beyond the orbits of the asteroids. In fact, the difference in the densities of the inner and outer planets and the sun, and the fact that practically all rotations and revolutions are in the same sense, suggest that our solar system once consisted of a sun and the outer planets, all having a very low density, and that in passing through a cloud of heavy meteoric matter, the density of the sun was slightly increased, and the inner heavy planets created; but it is impossible here to go into the details of these interesting questions.

As regards the nearer evidence of the earth's age to be sought for in the sedimentary rocks, no notice seems to have been taken either of the time required for the innumerable raisings and lowerings of level which certainly occurred during the coal periods or of the time which it must have taken to tilt horizontal strata through 90 degrees and more. Thus, Japan is being tilted at the rate of about 0.5 seconds per century, and if this tilting rate were steadily maintained in one locality, which is highly improbable, the Japanese strata would stand on end like our Cambrian strata in about forty million years' time. Yet, a few such tiltings were completed before some of our oldest strata were formed and overthrusts suggest a still greater antiquity for the age of sedimentary rocks.

* From *Nature*.

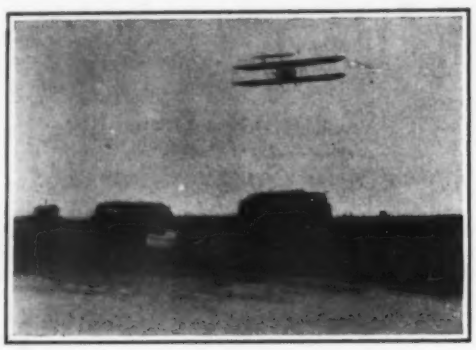
A New Weighing Balance

In some branches of chemical research it is now necessary to ascertain weights of substances in a vacuum, and considerable accuracy is also desirable. A new form of balance has been devised for this purpose that makes the weighing operation more simple and does away with much intricate mechanical detail, and a description of the new apparatus was recently given at a meeting of the Faraday Society, in England, by Dr. J. S. Anderson. The apparatus is essentially a current weighing balance reversed, as instead of weights being employed, one scalepan is replaced by a coil moving in the field of two fixed coils all connected in series and carrying an adjustable current. The details of the apparatus are worked out with great ingenuity, and a solenoid-operated lever is used for releasing and fixing the beam of the balance.

Coppering Iron and Steel

Although the surfacing of iron and steel with copper, when properly done, is best performed electrolytically, *Metal Industry* suggests a very convenient immersion process, but considerable experience is necessary to get satisfactory results. The article should be immersed in a solution consisting of one gallon of water at 160 deg. Fahr., sulphate of copper 7 ounces, and sufficient ammonia water (26 per cent) to neutralize the free acid and give a clear blue tint to the solution. An alternative plan is to tumble the articles in hardwood sawdust moistened with the solution. The articles must be perfectly clean or the copper will not cover well. It would be advisable to tumble the articles first in water to which is added about 4 ounces of carbonate of soda per gallon for fifteen minutes; then wash in clean water and immerse them in the solution or tumble them afterward as indicated. After coppering the articles must be carefully dried.

After the sixth exposure from the top the camera was stopped until the man had changed his clothes.



A popular "time trick photograph."
The landscape was made at one time, the aeroplane at another, and printed into the sky.

Memories of other days.
A scene made by printing in from two separate negatives, made at different times.

This is made in the same way as shown at left. While the camera is stopped the two specters come in.

Motion Picture Magic

What We See and What We Think We See

By C. H. Claudy

No HUMAN eye can see a bullet as it leaves a pistol and no human eye can see a soap bubble break. The slender colored sphere is before our eyes one instant—the next instant it is gone, but we did not see it go. We cannot tell, by looking at it, where it commenced to break, which side broke first, or anything about it, because its speed was greater than the power of our eyes to register.

But the camera can see.

Taking such pictures is not an easy matter, nor is it done as are the pictures of the growing flower. There a mechanism jerks the film forward, stops it, opens a shutter in the lens, closes it, and moves the film forward, all in the fraction of a second. But a sixteenth of a second, small interval through it may be for an ordinary moving object, is a long period of time for the bullet which may travel several thousand feet in one second. The interval between pictures and the time of exposure of the film must be minute indeed to catch many separate pictures of a bullet in a foot or two of space. No man-made mechanism could operate so fast—no shutter which human hands could construct could open and close fifty or a hundred times in the thousandth part of a second.

So recourse is had to other means. The light by which such photography is accomplished is that of the electric spark, which is the most instantaneous thing we know. A succession of spluttering sparks supplies the light, a continuously revolving wheel carries the film, and the bullet is so fired that it starts the sparks at the right moment.

When such a picture is thrown on the screen we see the bullet as a black shadow, slowly approaching the shadowy outline of the soap bubble. We see it depress the side of the bubble a little, then enter the bubble. More marvelous still, we see the bubble *close up* after the bullet has passed and show itself whole, with the moving bullet within it. We see the bullet pass on, touch the other side of the sphere, and come out. We see the ragged edge of the film left by the intruder, and then watch the whole film shrink together like a piece of rubber that is stretched and let go. The whole picture takes but a few seconds, but we are watching something in a few seconds which happened in a thousandth of a second or less—a hundred impressions of a bullet have been presented to our eyes, where the eye itself in nature would get none at all. Our time sense has been tricked—an instantaneous happening has been made to appear to occupy several seconds.

WHEN THE CARDS PLAY THEMSELVES.

Among the most popular trick films, and those which are most astounding in their apparent contradiction of the laws of nature as we know them, and of our sense of time, are those in which inanimate objects become animate. To see a deck of cards, for instance, on the table, whether in picture or in fact, is no matter of wonderment. To watch the top card slide off and over to the edge of the table, the second card follow it but stop at another place, and succeeding cards follow until five sets of poker hands have been dealt out by unseen fingers, is somewhat disturbing. We regard a dining-room table as a staid and placid piece of furniture. When it gets up and dances a jig, moves about the room, and finally out of the door and down the street, with a horde of small boys following it, it becomes peculiar to say the least. A wall paper expert papering a wall is not an unusual sight, but to watch the picture of a roll of wall paper which slops paste upon itself, then rears into the air and smooths itself out against a wall, is somewhat remarkable. A moving van full of household goods is familiar enough, but when it backs up to the curb and all the things in it tumble out, pell mell, rush up the steps and into the house, and we later see them arranging themselves in the house, the rugs placing themselves, the pictures hanging themselves, the dishes rolling into the china closet and the ornaments jumping to the mantelpieces, we may well be pardoned if we wonder how it is accomplished, even while we wish that things as we know them were as biddable!

ONLY TRICKING OUR SENSES.

Again, it is but a tricking of our sense of time. Impressions are conveyed to our brain of actions which seem to follow each other instantaneously, while as a matter of fact, in life, those same actions were separated by a considerable time interval. In the case of the pack of cards, the moving-picture camera is set up and a few pictures made of the pack of cards at rest. The camera is stopped, one card is removed by hand and slid forward an inch. A picture is made of it. The camera is again stopped, again the card is slid forward another inch (by hand, of course), and again a single picture is made of it. In this way, an inch at a time, successive pictures are made of the cards. It may take an hour or two to distribute five cards to five places about the table and make a picture of each card in every separate inch of its movement. It will take but half a minute to throw those pictures on the screen. The movement of the cards, which the observer thinks he sees, have resulted from a large number of separate placings of the cards by human hands. But as the hands were taken away before the individual pictures presenting the apparent motion were made, the observer of the pictures sees only the cards. Movements of the cards across the table which may have taken minutes to arrange and photograph are presented in a few seconds—again the tricking of our sense of time.

The same principle holds true of the pictorial representation on the screen of the movement of any inanimate objects—putty is molded by human hands, a little at a time, and photographed in many stages of its formation without the hands, and we see putty mold itself into the likeness of a face. Boards saw and plane themselves, then nail themselves into a box! Wall paper pastes itself upon the wall, dishes arrange themselves in a closet or upon a table, carpets cut, fit and lay themselves, and so on. Of course, there are some inanimate objects-in-motion trick films made without this intermittent picture action, as when a table is drawn along a street by an invisible wire. In this case our sense of the fitness of things is tricked, rather than our time sense, though the result is the same.

PICTURES THAT GET A LAUGH.

There are pictures thrown upon the screen which always get a hearty laugh, in which a man or a crowd move at speeds which we know to be quite impossible. One sees, for instance, the pictorial presentation of a runaway horse, in which horse, buggy and driver circle a tree, let us say, a dozen times in as many seconds; a crowd of men chase a supposed thief up and down the street and travel at the speed of an express train; a small boy runs up and down steps so fast that we cannot see his legs move. When these actions are interspersed with periods of natural movement, or complete rest of the moving figures, as if utterly exhausted, the effect is comical in the extreme.

Such pictures are but another adaptation of the principle of presenting to our eyes and brains as immedi-

A scene in the film shown on opposite page before the change of costume was made.

ately successive actions which really took place at widely separate periods of time.

The speeding of the flying figures, whether horse and buggy, running crowd or swiftly moving small boy, are made with a camera so arranged that every other picture, or every two out of three pictures, are omitted from the film. Thus, if we make an ordinary moving picture of a man running the length of a three hundred-foot block, we will take about two hundred and fifty pictures, supposing he runs the distance in fifteen or sixteen seconds. If every other picture is omitted from this strip, we will have then but one hundred and twenty-five pictures, yet they commence as the man commences to run, and finish with him at the other end of the block. It will take but half the normal period to project these pictures, so that the man will appear to run the hundred yards in seven and one half seconds, instead of fifteen. If two out of every three pictures are omitted, the film will be one third normal length, and the man will seem to run the hundred yards in five seconds—a quite impossible speed.

In the early days of motion-picture photography such trick films were made by actually cutting out every other picture and attaching the others into a complete film. Now, however, cameras are made which can make many "blank" exposures, without using film, for every picture they really expose, thus saving both time, trouble and the otherwise thrown-away film. The result is the same—action which actually takes a long time is shown as taking place in one half, one third or even less time—our sense of time is again tricked, and we laugh. Just why such pictures are laughable the psychologist must say, probably because our peculiar mental mechanism is invariably prone to laugh at that which it doesn't understand, and at that which our senses—both the five physical and the several mental—tell us is unusual and, therefore, unnatural.

NOT WHAT THEY SEEM.

Screen pictures of many things which seem to demand danger to the actors, if not actual suffering and death, are but time tricks in a film which may portray a serious drama. Thus, a man is thrown out of a window. First we see the struggle, then the man falling, see him land in a crumpled heap at the bottom and lie still, see friends rush up to him and pick him up, and then, confounding our first idea that a dummy was thrown out of the window, we see him feebly raise a hand to his head and speak!

Yet our first idea was right. It was two real men who struggled at the window's edge, and it is a real man who lies crumpled at the foot of the fall, *but it was a dummy which fell.* When the struggle is about to end in actual disaster the camera is stopped. A dummy is substituted over the edge of the window sill. The camera starts, and the dummy is thrown out and falls to the ground. Again the camera is stopped, the dummy is removed, and the actor who is supposed to be thrown out takes the place of the dummy. The camera is started, and the subsequent actions of the resuscitation of the "mangled" victim are pictured. Actions are presented as continuous to us who look, which are actually separated by several minutes of time. We have not sufficient time to examine the falling dummy and note that it *is not* a man, and the fact that a real man was struggling and a real man recovers from the fall, further convinces us that he really did fall. Once more our sense of time has been tricked.

It is in this way that bound victims to a railroad track are run over and automobile accidents are made to happen so realistically. A man bound to a railroad track is seen with the train thundering down upon him. But the train stops before it hits him, actually. So does the camera. A dummy is substituted, the camera starts, and the train comes on and runs over—the dummy. When the pose of the dummy and the man are carefully calculated to be exactly alike, we are completely deceived, for the train does not even hesitate—on the screen. We have no means of knowing that a ten-minute interval of time, during which the substitution of dummy for man took place, has been eliminated from the drama, and we are still children enough to have faith in "seeing is believing."

GHOSTS AND VISIONS.

Two events which take place at widely separated times may be presented at once on the motion-picture screen, and we have apparitions, ghosts, visions. A despondent husband sits by a fireside and gazes into the black ashes of his hearth. Suddenly we see in those ashes a picture of his wife—she is reading his letter of farewell and crying over it. We know perfectly well that the lady couldn't be down in the ashes; in the first place, there isn't room, and in the second place, she is too small, in the picture, to be real. What we don't know is that the lady cries and reads a letter in front of another camera and with a black background behind her, and that these pictures, purposely made smaller than the scale of the rest, are used, together with the picture of the sorrowful man, to make one print or positive film. Two events, two different times—we see one event at one time—result, a tricking of our sense of time and—magic!

The "sheeted ghost" is a time trick, the exposure being made as usual, after which the "ghost" walks into the scene and the rest of the exposure is made. The result is that the first exposure shows through the second, giving a "ghostly" effect. Two pictures made at different times, appear as one—hence the trick.

Thus, the motion picture makes Rip Van Winkles of us all. We are as those who go to sleep beneath the ether of the operating room. Events happen, and we know them not. Things are done, lives are saved, operations performed, and our brains have no knowledge of them. Like the tired man who sleeps thirty-six instead of twelve hours, a day is gone from our lives. In the motion picture it may be days, as in the case of the flower; or minutes, as in the "substitution" pictures; or several sets of small intervals, as in the moving cards, the animated saw and plane. But the *modus operandi* is the same—our sense of time is outraged, we see happen that which our normal experience tells us cannot happen, and so we go and go again, to watch the wonder of the magic of the motion picture, most of us unconscious of our sixth sense, still more indifferent to the fact that it is that, rather than our eyes, which the clever brains of the producers are tricking, tricking, all the time we wonder at the marvels that we *think* we see!

This shows the first scenes of the film, shown on opposite page, with a man sitting alone in a haunted house.

Here the man has changed to a dress suit, while the camera was stopped.

Heating and Ventilating

THE twin sciences of heating and ventilation, some future developments in regard to which Mr. A. H. Barker, Wh.Sc., outlined at the last meeting of the Society of Engineers, have received, but little attention in their scientific aspects. The complexity of the factors that go to make up a given result, and the difficulty of defining in terms of exact science what that result is or should be, are reasons for lack of progress in the science of the subject, and added to this one has to take into account the variability of human physiology and psychology as an essential part of the problem.

Physiologists are not even agreed as to what is a healthy temperature for human beings to live in. The heating and ventilating engineer aims at producing comfort, but is baffled by the fact that a man is comfortable only when he thinks he is. Air which, judged by chemical analysis, is impure may feel fresh and sweet, and *vice versa.*

The only legitimate function of the engineer is to produce and control specified movements of air and other effects, while it should be the duty of the physiologist and hygienist to specify what are healthy and comfortable conditions. In connection with heating, the expression "temperature of a room" is generally understood to mean the reading of a thermometer suspended in the room, but this reading does not necessarily indicate the temperature of the surrounding air, or form a reliable guide to the feelings of the occupants of the room. The air temperature, the radiant temperature, the quantity of convected heat, and the quantity of radiant heat must all be determined, but first the relation between the thermometer reading, the air temperature, and the radiant temperature must be determined.

The freshness of air in a building depends on keeping the air temperature relatively low and the radiant temperature high. The chemical composition of the air has, within wide limits, no effect on the human organism, whereas its temperature and humidity are very important.—*The London Daily Telegraph.*

In this scene the man asleep in the haunted house awakens to find a specter sitting on either side of him.

The Theory of Cold Light*

Can Light Be Produced Other Than By Temperature Radiation

By Wilder D. Bancroft, Professor of Physical Chemistry

WHEN opaque substances such as carbon, platinum or earthenware are heated sufficiently they emit light, the quality and intensity of which depends on the temperature and not on the nature of the substance heated. Radiation of this sort is called temperature radiation. An opaque gas would also emit light if heated to a suitable temperature. Iodine vapor, for instance, glows[1] when heated to above 500 deg. Cent. While this may not be entirely a temperature radiation, it is usually so considered. The law of temperature radiation holds only for opaque substance, which are sometimes called perfect radiators. An absolutely transparent substance would give no temperature radiation. At the end of the eighteenth century Wedgwood[2] showed that heated air is not luminous. Subsequent experiments have confirmed this conclusion of Wedgwood's.

Most artificial lighting is due to temperature radiation from solid particles. In the kerosene lamp the light is due to glowing particles of carbon. The difference between the kerosene lamp and the gas jet is that the temperature of the latter is higher. If all the solid particles are burned, as in the Bunsen burner, a so-called nonluminous flame is obtained, even though the temperature is much higher than in the burner with a lumnious flame. The brilliancy of the lime light is due to temperature radiation from intensely heated lime. In the Welsbach mantle and in the Nernst lamp there are suitable mixtures of rare earth oxides instead of the calcium oxide used in the lime light. There is some question whether the light from the Welsbach mantle is exclusively due to temperature radiation, but it is unnecessary to go into that matter now.

At first one would suppose that the incandescent lamp would give the most efficient temperature radiation known because graphite melts at a higher temperature than any other known substance. The carbon lamp can be made to give an extraordinary light efficiency, but its life is extremely short under these conditions. The graphite vaporizes or disintegrates and the filament breaks.[3] There has, therefore, been a systematic search for substances with high melting points and low vapor pressures. As a result, there have been produced successively the osmium, the tantalum, and the tungsten lamps. In the nitrogen-filled tungsten lamp the thermal radiation has been cut down and consequently less power is needed to heat the filament to a given temperature.

While it would be foolish to claim that the limit of efficiency has been reached, it must be remembered that a large number of very able men have been attacking this problem of temperature radiation systematically and that consequently the limit of efficiency is probably being approached. That brings up the question whether light may not be produced in other ways than by temperature radiation and, if so, whether it is possible to produce cold light. The possibility of cold light cannot be disputed because the firefly produces it. Langley's studies of the firefly have shown that the insect gives about 95 per cent efficiency, meaning thereby that 95 per cent of the radiations are in the portion of the spectrum visible to the human eye while only about 5 per cent of the radiations are in the ultra-red portion of the spectrum and what are popularly called heat rays. The light of the firefly cannot be due to a temperature radiation because the firefly does not burn up instantaneously. It is not a question involving life because the abdominal portion of the firefly can be dried, pulverized in a mortar, and kept for two years. At the end of that time the powder will glow if moistened and exposed to oxygen. It is simply an oxidation process. The firefly has the power of secreting a substance which burns with a luminous, cold flame. If one were to make in the laboratory the unknown substance which the firefly makes, it would behave in exactly the same way as the natural product. It would be amusing to do this; but that is all that it would be, because the product would be too expensive to use as a source of light. Nobody claims for the firefly a low cost of production. In fact, it is not known how one would estimate the firefly's cost of production.

Under certain circumstances cold light can be produced in the laboratory. Angström[4] has calculated that he gets about 95 per cent light efficiency when he passes a current through nitrogen under 0.1 mm. pressure. The losses at the electrodes and at the walls of the tube cut the working efficiency down to about 8 per cent. From this work of Angström's, it seems probable that the Moore light is not a temperature radiation but is due to chemical reactions.

Phosphorescing substances, such as zinc sulphide, emit light at low temperatures and do not involve temperature radiations. As yet, however, such substances as Balmain's paint, etc., have to be exposed to light before they will emit light. Until some other way of stimulating them is found, they are of more theoretical than practical importance. At present very little is known about the chemical reactions involved, because these substances have been studied chiefly by physicists.

The luminescence of salt flames are of great importance theoretically. By putting different salts into the non-luminous flame of a Bunsen burner different colored flame are obtained: yellow with sodium, pink with lithium or strontium, blue or green with copper. Since the temperature of the flame is about the same in all these cases and since one cannot very well claim selective absorption in each case, it seems certain that the colors of these flames are not due to temperature radiation and the problem is to find out what does produce the luminescence.

One usually gets the same yellow color with different sodium salts and one is consequently tempted to say that the yellow color is due to the sodium atom when heated to a suitable temperature. This is not true, however, because sodium salts emit little or no yellow light in the hydrogen-chlorine flame, even though this is fully as hot as the flame of the Bunsen burner.[5] The next assumption is that the yellow color is due in some way to sodium metal and that the metal is present in one flame and not in the other. The presence of free metal in the flame is not impossible. Almost all salts are formed with evolution of heat and consequently will dissociate if the temperature is high enough. It, therefor, becomes a question of fact whether a given salt dissociates in a given flame or not. To test this, use has been made of a modification of Deville's hot-cold tube. Cold water was run through a porcelain tube and the chilled porcelain tube was held in the colored flame. With salts of copper, cadmium, tin, silver, lead, bismuth, zinc, antimony, and arsenic in the Bunsen flame, mirrors of the metals were obtained on the porcelain tube.[6] With salts of mercury a gray deposit was obtained consisting of drops of mercury. No experiments were made with gold or with the platinum metals. No mirrors of tungsten or molybdenum could be obtained from oxides of these metals in the Bunsen flame, but good mirrors were obtained with the hotter oxhydrogen flame. From the cooler portions of the oxyhydrogen flame tungsten blue and molybdenum blue were precipitated on the tube. When sulphur dioxide was led into the hydrogen-air flame, sulphur was precipitated on the porcelain tube. No copper was obtained when copper salts were fed into the hydrogen-chlorine flame, showing that the amount of metallic copper present in this flame is at any rate very much less than in the Bunsen flame.

It is not to be expected that mirrors of metallic sodium and potassium would be produced. There is, however, some evidence that the metals are actually precipitated. The sodium chloride is distinctly alkaline when precipitated from the hottest flames. This is probably not due to hydrolysis in the heated gases, because caustic soda is more volatile than sodium chloride and consequently should be found in larger amounts in the outermost portions of the flame. This is not the case, for the sodium chloride from the outside of the flame is neutral. The greatest alkalinity is obtained under the conditions under which one should expect to have the largest amount of free metal. While this is not absolutely conclusive in itself, it is pretty satisfactory when taken in connection with the behavior of the other metals.

It is evident that a number of reactions are taking place simultaneously in a flame colored with a salt. It is now believed that all reactions tend to emit light[7] and that they all emit light if made to take place very rapidly, the critical reaction velocity varying enormously in different cases. It is known that increasing the rapidity of a reaction which emits light increases the intensity of the light[8] without producing much change in the quality. While the vaporized salts are sometines colored, as in the case of cupric chloride, and may, therefore, give temperature radiation to some extent, it is clear that most of the light emitted by salt flames is due to chemical reactions and is to be classified as chemiluminescence.

Some progress has been made in determining the reaction corresponding to a given color. The following results[9] were obtained for copper salts in the Bunsen flame:

I. Cuprous ion to cuprous salt = red.
II. Copper to cuprous ion = green.
III. Cuprous ion to cupric salt = blue.

The first conclusion is based on the action of cathode rays on cuprous iodide, the third on the combustion of cuprous chloride in chlorine, and the second on the combustion of copper in oxygen. A number of experiments were made on the rapid reduction of cupric and cuprous salts with sodium and aluminium as reducing agents. No characteristic luminescence could be obtained, presumably because these reverse reactions were not made to go sufficiently rapid. However that may be, it is clear that reductions play no important part as regards the light emitted by copper salts in the Bunsen flame.

When a solution of cupric chloride in aqueous hydrochloric acid is sprayed into the Bunsen flame, there is a red or violet tip to the flame and when the flame is burning steadily one can often see a violet sheath around the flame. This is not a true luminescence, though it looks like one. It is merely the color of cupric chloride vapor. It can be obtained in mass by heating copper in an electric furnace and then running in chlorine or by volatilizing cupric chloride.

When cupric chloride is sprayed into a hydrogen-chlorine flame or when a mixture of cupric chloride and hydrochloric acid is sprayed into a Bunsen flame, the hydrochloric acid cuts down the dissociation of the cupric chloride and there is a reaction from cuprous ion to cupric salt but not the reaction from copper to cuprous ion. Consequently the flame is blue and not green. The same result ought to be obtained without the acid if one used a flame the temperature of which was not sufficient to dissociate cupric chloride into free metal and chlorine. The alcohol flame is just on the dividing line. Cupric chloride colors a hot alcohol flame green and a cooled alcohol flame blue.

Since the yellow of the sodium flame is due to the reaction from sodium to sodium ion, the hydrochloric acid from a hydrogen-chlorine flame will force back the dissociation and cause the yellow to disappear practically completely.[10]

Since the bulk of the light in salt flames is due to chemical reactions and not to temperature radiation, there is a possibility of duplicating the effect, if one can cause the reactions to take place sufficiently rapidly at low temperatures; in other words, if they are done electrolytically. Some years ago Schluederberg[11] showed, in the Cornell laboratory, that light is emitted when an alternating current is passed through lead electrodes in sulphuric acid. Later, Wilkinson[12] obtained flashes of light with a number of metals as anodes, using a direct current. Owing to film formation, the light could only be seen for an instant. By pressing a tooth brush against a rotating anode, it is possible to remove the film as it gets too thick and thus to obtain light continuously for an indefinite period, ten minutes for instance. So far we have not been able to obtain an electrolytic flame with copper which could be shown to a large audience, but we can do this readily with mercury.[13]

When mercurous bromide or mercury is burned in bromine an orange light is emitted. When mercurous or mercuric bromide is exposed to the cathode rays a similar orange light is obtained. When mercury is made anode in a cold, fairly concentrated, potassium bromide solution (25 per cent, for instance), with an anode current density of about 2 amperes per square decimeter, the mercury first becomes coated with a film of bromide and then appears to glow with a brilliant orange light. This will last for at least ten minutes, at the end of which time the film of bromide will have become so thick as to prevent the light being seen. By looking carefully from the side, light can still be seen between the film and the surface of the mercury. The light can be obtained at as low a voltage as 3 volts, but the intensity is then very

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*A paper read at a meeting of the Pittsburgh Academy of Sciences and the Illuminating Engineering Society.

[1] Salet; *Ann. Chim. Phys.* (9) vol. 28, p. 34; 1873. Cf. Bancroft and Weiser; *Jour. Phys. Chem.*, vol. 18, p. 295; 1914.

[2] *Phil. Trans.*, vol. 82, p. 272; 1892. Cf. Bancroft and Weiser; *Jour. Phys. Chem.*, vol. 18, p. 281; 1914.

[3] Werner von Bolton obtained 0.3-watt per candlepower for a moment with a tantalum lamp.

[4] *Wied. Ann.*, vol. 48, p. 493; 1893.

[5] Cf. Bancroft and Weiser; *Jour. Phys. Chem.*, vol. 19, p. 310; 1915.

[6] Bancroft and Weiser; *Jour. Phys. Chem.*, vol. 18, p. 261; 1914.

[7] Bancroft; *Jour. Franklin Inst.*, vol. 175, p. 129; 1913.

[8] Trautz, *Zeit. Elektrochemie*, vol. 10, p. 595; 1904. *Zeit. Phys. Chem.*, vol. 53, p. 108; 1905.

[9] Bancroft and Weiser; *Jour. Phys. Chem.*, vol. 18, p. 323; *Trans. Am. Electrochem. Soc.*, vol. 25, p. 123; 1914.

[10] Bancroft and Weiser; *Jour Phys. Chem.*, vol. 19, p. 310; 1915.

[11] *Jour. Phys. Chem.*, vol. 12, p. 623; 1908.

[12] *Ibid.*, vol. 13, p. 695; 1909.

[13] Bancroft and Weiser; *Jour. Phys. Chem.*, vol. 18, p. 762; 1914.

low. With increasing voltage—or really with increasing current density—the intensity of the light increases, the upper limit coming when visible sparking takes place. The phenomenon is shown very well with a voltage of 24-28 volts.

This is not cold light. It is not even a very efficient light. The importance of it lies in the fact that it is a striking illustration of the principle that reactions emit light and that a high temperature is not essential. To obtain cold light one must find a reaction which can be made to go rapidly, which absorbs heat or evolves but a small amount of heat, and which has a high conversion factor for light. A number of other requirements come in, if it be stipulated that the light shall be suitable for commercial purposes. There is no immediate prospect of the present methods of lighting being superseded; but the theoretical feasibility of cold light and the general conditions under which it is to be obtained have been demonstrated.

Your Lighting Bill for 1925

By Albert W. Deininger

WONDERFUL progress has been made in the science of illumination in the past ten years. What will be achieved in that field in the next decade?

Let us examine briefly the recent progress, and, knowing the present tendency, predict if we can the future of illumination.

Table I gives the recent achievements in gas lighting while Table II considers electric lighting for a corresponding period.

TABLE I.—GAS LIGHTING.

Burner.	Relative Amounts of Gas for Same Amount of Light.
Prior to 1905—Open flame	1.00
1905 to 1910—Upright mantle with fluted flat cone reflector	0.26
1910 to 1915—Inverted mantle with prismatic reflector	0.11

From Table I it will be seen that an inverted mantle burner with a prismatic reflector uses only one ninth as much gas as an open flame burner giving the same amount of light.

The common open flame burner consumes 5 cubic feet of gas per hour while the ordinary inverted mantle burner consumes 3 cubic feet. It naturally follows, therefore, that the gas consumption will be reduced 40 per cent and the intensity of illumination be 5.4 times as great if open flame burners are replaced by inverted mantle burners with prismatic glass reflectors.

TABLE II.—ELECTRIC LIGHTING.

Incandscent Lamp.	Relative Amounts of Electricity for Same Amount of Light.
Prior to 1905—Carbon filament with opal cone reflector	1.00
1905 to 1910—Gem lamp with opal cone reflector	0.82
1910 to 1915—Tungsten filament with prismatic glass reflector.	0.36

Thus, at the present time using tungsten lamps with prismatic reflectors we obtain 2.8 times as much effective illumination for the same power as we could obtain using carbon lamps with opal cone reflectors.

While the relative increase in efficiency of gas and electricity as illuminants is interesting, the thing that interests the consumer is the most economical method of lighting. Table III gives the cost per thousand lumen hours of gas and electric lighting for the three periods of time considered. The costs of gas and electricity are the averages for the periods, the methods of lighting being as given in Tables I and II. The walls of the room considered are of medium color, neither very light nor very dark.

TABLE III.—COST OF ILLUMINATION PER THOUSAND EFFECTIVE LUMEN HOURS.

Prior to 1905.

Gas $1.50 per thousand cubic feet. Electricity $0.20 per kilowatt hour.

	Power.	Cost.	Relative Cost.
Gas	61.00 Cub. ft.	9.15 Cents.	1.00
Electricity	0.70 kw. hrs.	14.00 Cents.	1.53

1905 to 1910.

Gas $1.25 per thousand cubic feet. Electricity $0.15 per kilowatt hour.

	Power.	Cost.	Relative Cost.
Gas	16.00 Cub. ft.	2.00 Cents.	1.00
Electricity	0.57 kw. hrs.	8.55 Cents.	4.28

1910 and including the present time.

Gas $1.00 per thousand cubic feet. Electricity $0.10 per kilowatt hour.

	Power.	Cost.	Relative Cost.
Gas	6.80 Cub. ft.	0.68 Cents.	1.00
Electricity	0.25 kw. hrs.	2.50 Cents.	3.68

It will be noted in Table III that gas lighting costs only 7.4 per cent of the cost prior to 1905, and that electric lighting costs only 18.2 per cent of the cost prior to 1905. At present electric lighting costs 3.68 times as much as gas lighting, the replacement cost of gas mantles and tungsten lamps being very nearly the same.

The question naturally arises as to whether further increased lighting efficacy is possible. It unquestionably is possible and highly probable. The inverted mantle gas burner gives out as light only one half of one per cent of the energy in the gas consumed and the tungsten incandescent lamp only about 5½ per cent of the electrical energy consumed as light.

The latest and most efficient incandescent lamp is the inert gas or nitrogen filled incandescent lamp. It has a tungsten filament but the bulb is filled with nitrogen—an inert gas. At present, the lamp is used commercially only in large sizes of several hundred watts. The nitrogen-filled tungsten lamp is, in large sizes, about twice as efficient as the ordinary tungsten lamp, and if made in small sizes, will cause ordinary illumination by electricity to cost only about 80 per cent greater than illumination by inverted mantle gas lights if the relative cost of gas and electricity remains the same as at present.

Lighting has passed through a combustion stage where illumination was obtained by burning tallow, oil and finally gas. We are now in the incandescent era, light being obtained by the incandescence of the mantle of the gas lamp and the filament of the incandescent electric lamp. The limit of illuminating efficiency by incandescence is believed to be at hand. The next era is believed to be one of luminescence in which light will be obtained by causing a gas in a bulb to glow by passing an electric current through it. The efficiency of the luminescent lamp is expected to be very high.

Gas, as an illuminant, will probably have but a small place in the luminescent era if the expected efficiency is realized in the luminescent lamp. Gas would still be used, but chiefly as a power gas, as it would not be an efficient illuminant. A similar condition existed in the period during which the open flame gas burner and the carbon filament indandescent lamp were in use, it being possible to use a given amount of gas in a gas engine driving an electric generator lighting carbon incandescent lamps and obtain twice as much light as the same gas would give from open flame burners. The introduction of the mantle type of gas lamp alone prevented gas from being discarded as an illuminant. The efficiency of the gas lamp has been improved three times as much as the electric incandescent lamp since that time so that that condition no longer holds.

One hundred per cent increase in the efficiency of the electric incandescent lamp, which is expected in the nitrogen-filled lamp of ordinary size, should make it more profitable to operate electric incandescent lamps from a generator driven by a gas engine than to burn the gas in inverted mantle gas burners in a fair sized building.

Neglecting interest, depreciation, and attendance charges 100 per cent increase in the efficiency of the electric incandescent lamp would cause electric lighting by incandescent lamps using purchased power to be 80 per cent more expensive than gas lighting by inverted mantle burners, or 140 per cent more expensive than illumination obtained from incandescent lamps lighted by a generator driven by a gas engine if the relative charge for gas and electricity remains the same as at present.

It is unlikely that the efficiency of gas lighting will be improved materially. Gas, as an illuminant, will have to compete with electricity by lowering the charge per thousand cubic feet. When the open flame burner is discarded the price of gas may be lowered considerably as the mantle type of lamp requires heat only and therefore a cheap gas of low illuminating efficiency may be used.

Thus it will be observed, that within a few years we may expect electric incandescent lighting bills to be cut in two because only half the power used at the present will be required, and gas lighting bills to be considerably lower because cheaper gas will be in use.

Now, take your guess as to your lighting bill in 1925, and by the way, will it be for gas or electricity, and if for gas will you burn it or use it in a gas engine driving a generator that lights incandescent lamps?

Triplex Glass

ONE of the most recent French productions is known as "triplex glass," and it is claimed to afford a remarkable security against breakage of glass panes, especially as regards accidents due to projected fragments of glass. This new invention is the outcome of considerable research, and consists in the makeup of a glass pane which uses two plates of glass with a sheet of transparent celluloid between them, the whole being suitably cemented and pressed together. Such combination glass has some remarkable properties in the way of strength, but at the same time it is quite as transparent as ordinary glass. Before this time a product known as reinforced glass was brought out, consisting of a pane having wire netting of large mesh imbedded in it. This was a step in advance, but was far from solving the problem, as will be seen from the fact that the amount of fragments projected by a shock of equal force upon a glass pane is for ordinary glass 80 per cent of the surface, for armored glass 30 and for the new triplex glass only 2 per cent. Great safety is thus obtained, and especially for automobile use. Statistics show that over half the number of wounds to chauffeurs and occupants come from projection of glass fragments due to a collision or from a shock, this latter being either direct or recoil. Even passers by are wounded in this way. Mortal wounds by veritable blades which pierce the body like a poignard, or less grave ones where the face is mutilated, are on record. Reinforced glass was tried for this purpose, and here the danger is much less, and the quantity of fragments smaller, though as above seen, it is still considerable. But for automobile use such glass is scarcely practicable because of its unesthetic appearance which gives a cage-like effect, and a still greater drawback is that when placed before the driver it causes difficulties of vision, these being still further increased by sunlight or rain.

The new triplex glass appears to solve the problem of an extra strong as well as a perfectly transparent glass, and there is no fear of the celluloid becoming yellow with time, for this coloration is due to contact with the air and cannot now be produced because the celluloid is hermetically sealed between the two panes. But once given the idea, it was not by any means easy to realize in practice, and the inventors worked at it for over two years in order to elaborate the process; this consists in the preparation of the glass panes and the celluloid sheet, cementing together, pressure under hydraulic press and cutting into shape. Even in the shop the cutting is difficult, which shows its great strength. Each glass pane is run over by the diamond, but the pane is as yet far from being cut as a whole. It is placed upon a heating table so that the cut will widen by expansion, then it is bent back and forth a number of times as for a cardboard sheet so that the celluloid is detached by breakage along the edge. This applies to straight line work, but for curved pieces, such must be made up by assembling three pieces of the right shape beforehand, for it is practically impossible to cut out such shapes in the assembled triplex glass. Very good protection against burglars is thus afforded.

Some experiments were made to show the strength of the glass against shocks from a projectile. In a stout wood frame were placed in turn three plates about 8 inches square, the first in ordinary glass 0.2 inch thick, the second in 0.28-inch reinforced glass and the third in triplex glass of only 0.16-inch thickness. Shocks of the same value are given to each pane by hanging a metal ball of about 1 pound weight from the ceiling on a 13-foot cord and using a suitable release device at the ceiling so that the ball swings down and strikes the glass with considerable force. The results afford an instructive comparison. For the ordinary glass, there remained but few fragments in the frame, and splinters were projected for 15 feet. The reinforced glass suffered much less, but its center was torn out and shattered, debris being found 18 feet distant. A great difference was seen for the new glass, and it was simply cracked in the part lying around the point of impact, the ball stops without penetrating the pane, and a few fragments (not over 2 per cent) fall at less than 8-inch distance. It is easy to see what would be the case in an accident. As to a recoil shock, the new glass holds up remarkably well here. For instance, a glass door is violently closed, in which case the pane flies in pieces, but with the new glass it is simply cracked in zigzag without detaching any pieces. A still more remarkable effect is seen by using two triplex glasses laid together and mounted in a frame, and here an unusual strength is obtained. The hardest hammer stroke only produces star-shaped cracking, but does not cause pieces to separate, and no splinters are produced. Revolver firing also proved its great strength. A double pane was mounted in a frame at 20 inches in front of a 2-inch plank, and this served as a target for revolver firing at 20-foot range. The ball made a hole in the glass without splintering, and struck the wood; but the resistance due to the glass was so great that the ball could not penetrate the plank and only left a mark on the surface. Such a result is unusual and is worthy of attention, for in the absence of the glass, the ball easily perforates the plank. The uses of the new product appear to be numerous. As it is refractory to the diamond, panes for show windows are safe against burglars. Because of its high resistance to recoil shocks, it is good for use in window sashes or glass doors which are subject to sudden closing. Another use is for greenhouse sashes, and especially for horticulturists and market gardeners this gives a good protection against hail, even in the case of severest storms. But the new glass will no doubt find its most practical application in carriage work, and especially for automobiles, and in this field there is a great need for a product of this kind in order to avoid the frequent accidents which are caused by breakage of glass.

Fig. 1.—On the Bay of Goulven (Finistère).

Fig. 2.—In the dunes of Paris-Plage.

Fig. 3.—The ebb at Cape Ferret, Bay of Arachon.

Ripple Marks*

A Study of Water Action on the Seashore

By Ch. Epry

Among the multitudinous impressions which the ebbing tide leaves on the sands as it recedes the most curious are certainly those parallel lines of ridges, of varying size or regularity, covering at times immense areas of the beach. They are known in French as *Paumelles*, which has no significance, and in English as ripple marks, which name has prevailed, perhaps because it is foreign, or perhaps because it is more expressive (Fig. 1).

Ripple marks are everywhere so common that it is impossible to walk on any beach for a few minutes without encountering them and admiring them, as they always present very beautiful appearance, especially when seen in large masses in the sunlight, although one may suffer from them, perhaps, if one is barefooted, as they make walking very difficult. However, although they are universally known, no one seems until now to have definitely ascertained their cause.

Some regard these undulations as due to the waves alone; others consider that they are caused by the wind, by the transference of the surface vibrations to the bottom, when these have only a little depth of water to traverse in order to reach the latter. Learned theories have also been formulated to explain them, none of which give entire satisfaction.

The question still remained, therefore, "What causes the formation of these ripple marks?" Wishing to answer it, I have taken the opportunity, during a number of years, to observe attentively these undulations wherever my tastes and fancy have taken me; that is to say, from one end of our coast to the other, and the cause of the phenomenon appears to me to-day so easy of comprehension that I find it difficult to explain to myself why an agreement regarding it was not reached long since. It is the very definite conclusion at which I have arrived that I present here. Although it is simply that of an amateur who can only bring to his researches a measure of curiosity and much patience, I believe that it will impress itself on others with the same force that it has on me, if they will consent to accompany me, stage by stage, along the road which has led me to it. In order to simplify the explanation and clarify the text, I shall present in connection with each argument the most convincing of a number of photographs which I have taken on different beaches.

In the first place, then, where are these ripple marks formed? Broadly speaking, ridges of this kind are produced beyond the reach of the waves on the dry sands of the interior of dunes (Fig. 2) and likewise on the sandy slopes of Sahara, or the snow carpet of Alpine heights. Due without question to æolian action, these do not interest us, at least for the present, though we shall have occasion to return to them later.

In the area in which the ebb and flow of the tides manifest themselves it is necessary to distinguish between an upper and a lower beach. The first presents a particularly steep slope, and the water only reaches it during the neap tides. But then the water possesses a much greater force, because it must, during the same number of hours, traverse a longer course. For these two reasons the layers of water which are spread out, however thin they may be, are carried about with such velocity that no other force can counteract their effects. But their action is vertical. The grains of sand are energetically propelled from below upward and from above downward, but solely in a vertical direction. Consequently, children's modelings, foot-prints, or ridges raised perhaps by the wind during the time when the sand is drying, all inequalities indeed, whether depressions or elevations, are erased or thrown down, as the smoothed-out slope takes on the regular surface of a glacis (Fig. 3). Fig. 3 shows the sea at work; Fig. 4 enables one to judge of the final result.

On the upper beach ripple marks are never found. They occur, in contrast, in great abundance on the lower beach, as shown in Fig. 1—in great abundance, but not always, nor everywhere. Fig. 5 is a view taken

Fig. 4.—The sea leaving the upper beach at Etables (Côtes-du-Nord).

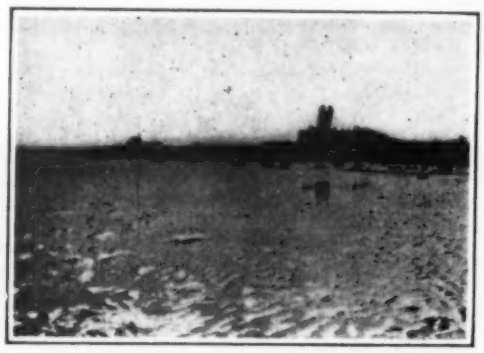

Fig. 5.—On the Bay of Goulven, the "Roc'h Vran."

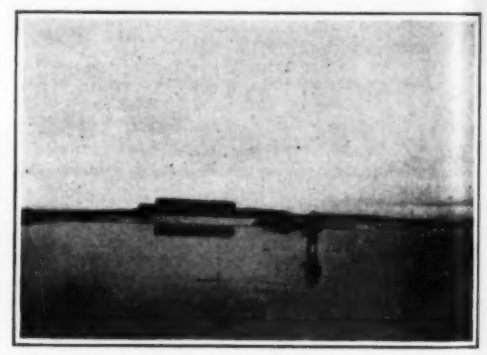

Fig. 6.—Appearance of the lower beach at Fort-Bloqué when the water is receding.

Fig. 7.—Ripple marks below Lesconil.

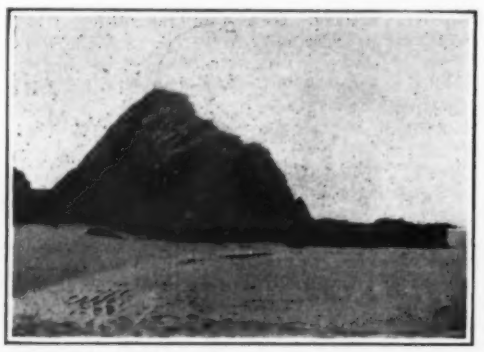

Fig. 8.—Strip of beach between Pouldu and Douëlan.

Fig. 9.—Preceding beach seen from a greater distance.

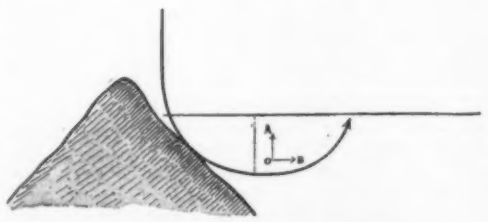

Fig. 10.—Curve of wave after striking rock.

* Translated by permission from the Annales de l'Institut Oceanographique (Fondation Albert 1er Prince de Monaco), Paris, vol. 4, pt. 3, 1912. Reprinted from the Annual Report of the Smithsonian Institute.

in the Bay of Goulven on the same day and at the same hour as Fig. 1, and scarcely a hundred meters to the right of the place where the latter was taken and toward nearly the same point of the horizon. The two photographs placed side by side constitute a panoramic view of the same landscape. The ridges, which are so beautifully shown at the left, are irregular and scarcely outlined at the right, presenting merely a wavy appearance.

Let us go elsewhere. Here is a beach in the region of Lorient, that of Fort Bloqué, quite ideally flat, and apparently well suited for the formation of ripple marks. (See Fig. 6.) A fisher woman is walking toward the rocks, which begin to appear above the water, to collect periwinkles. The water, consequently, is receding. One, however, perceives no trace of its having covered the sands. Their remarkably smooth, wet surface has the polish and the gleam of a mirror.

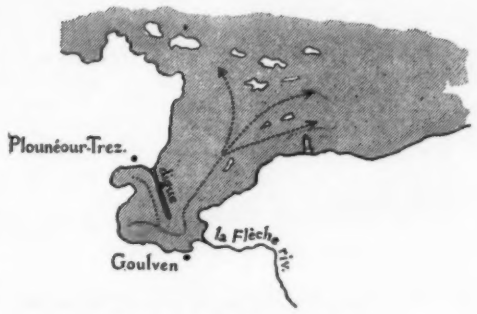

Fig. 16.—The Bay of Goulven.

In contrast, in many places, especially near the time of the very low water of the spring tides—for example, on the bars that form at the mouth and along the banks of certain rivers—ripple marks are found, which, unlike those shown in Fig. 1, are not a few centimeters high, but 50 to 75 centimeters, or even a meter. Such ripple marks are shown in Fig. 7, from a photograph taken at the mouth of the Steir,[1] or lagoon of Lesconil.

As the ripple marks, then, do not form on the upper part of the beach, but are extremely common on the lower part (which corresponds in sandy regions to the zone of fucus and laminarian seaweeds of rocky shores) does it not seem that it ought to suffice, in order to discover their origin, to note the points in which the latter differs from the former? This reasoning is correct, and it is possible to draw important conclusions from this comparison. From this point of view, however, it is of importance to proceed in one's deductions with a prudent circumspection, without taking one's eyes from the facts; otherwise, one is in much danger in a moment of inattention of arriving at an explanation of the phenomenon, which, when pursued a little further, will very quickly surprise one by becoming in complete discord with all the new data acquired by observation.

What, then, is the principal difference between the two parts of the beach, from the particular point of view which we are taking? The slope of the lower beach is much more gentle, so gentle at times that the waves in certain regions recede for a distance of several kilometers in attaining the level of low water. Consequently, the velocity of the current of the tide is there very great. In the Bay of Mont-St. Michel it is equal to that of a horse galloping. On the other hand, throughout the duration of the flowing tide, the progressing stratum of water which moves up the sands is very thin, so thin, indeed, that the waves cannot perpetuate themselves and die out at a considerable distance from the shore. These beaches are, while they last, like immense shallow lakes which gradually empty themselves. What is one to conclude from such a state of things? Given the slight thickness of the layer of water, it seems quite natural to believe that the action of the wind should make itself felt at the bottom, forming there ridges analogous to those which it raises on the surface of the sea. One may equally be led to inquire whether it is not necessary to attribute the formation of ripple marks to the violence of the current of the tide that sweeps this very flat area, or to the indirect action of the wind, or in some measure to the action of the two elements, the air and the water.

The second hypothesis has been very generally adopted. At first sight, we repeat, it appears very convincing. In reality, it does not bear serious examination, and should be resolutely rejected. Whatever the state of the atmosphere, indeed, one will observe that on a beach there are certain points where at all times, or at least with very great regularity, ridges are formed. At other points on one day they will disappear, though the wind may blow a gale, while on the morrow they reappear, though the sky may be calm and the sea like glass.

Not only is there no correlation between the movements of the aerial ocean and the wrinkling of the sandy surfaces submerged under a very thin stratum of water, but on looking closely, one observes that it is particularly in those places where the bottom is especially protected from the influence of the wind that these marks attain their largest dimensions; for example, where the ground is accidentally sunken, in the depths of pools, or on the banks of small streams, or at low-water mark; again, where the force of the current of the tide, as well as that of the wind, whatever it may be, remains comparatively negligible, and is actually without effect, for example, on the sands of bars, which are exposed only a few minutes, and then only at the equinox, at the mouth of rivers and streams.

One should not have a shadow of doubt on this point. Ripple marks are the work of the tide, and of that alone, as they are nowhere so numerous and conspicuous as where the sands are best protected from the effects of the wind.

This first point settled, it remains to harmonize this assertion with what we have said of the effects of the tide on the higher part of the beach, where far from producing a greater wrinkling of the bottom, the increase of its speed, owing to the great inclination of the beach, causes a general leveling.

In order to explain this apparent contradiction, and find the solution of the enigma, which of the two factors is it necessary to consider, the inequalities of the two slopes, or the difference between the dynamic effects of a breaking wave and those of a regular current? It is, in fact, neither the one nor the other. They are of no importance. All research in this direction leads to nothing. Here again is an impasse to be avoided. The solution of the problem is to be sought elsewhere. In order to discover it without further delay, we must transfer ourselves to a point on the shore where the ripple marks always, or nearly always, form; that is, to the line of junction of the upper and the lower beach. This line of demarkation, sometimes scarcely visible, is remarkably clear in the accompanying illustration (Fig. 8).

Examine this photograph closely and what do we see? A higher beach which is perfectly smooth, a lower beach, almost horizontal, equally leveled off by the sea that has withdrawn from it. Between the two, at the base of the upper slope, are two small pools quite distinctly united, of which the bottom in course of becom-

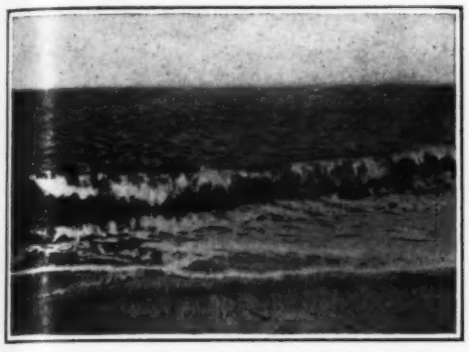

Fig. 11.—First rough outline of ripple marks.

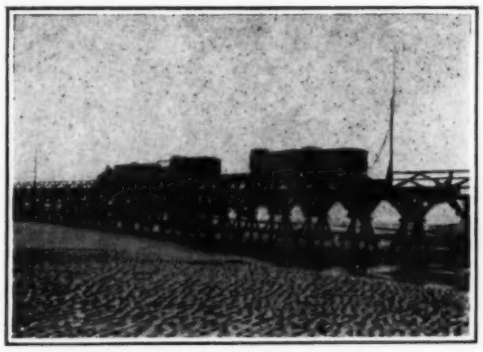

Fig. 12.—On the Bay of Somme.

Fig. 13.—An elbow of the Trieux.

Fig. 14.—Across the Bay of Goulven.

Fig. 17.—Sand dunes in the desert of South Tunis.

Fig. 18.—Mud bottom in the stier of Lesconil.

Fig. 19.—Desert of mud at low tide between the mainland and the Island of Oléron.

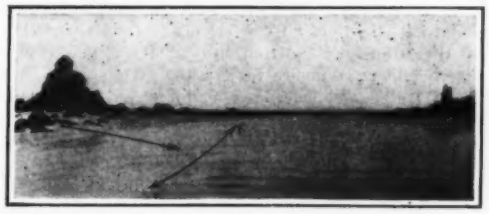

Fig. 15.—The Bay of Goulven.

[1] The Steir is a little Breton river, which empties into the Odet at Quimper. But in that region they designate thus most of the small creeks without name that toward the ocean spread out into fjords, estuaries, or lagoons.

ing dry is covered with ripple marks. Why are these ridges formed there and not higher up or farther out?

Let us pursue our examination, concentrating our attention on the nearer depression the details of which are the more distinct. In the widest part of this pool the ridges are arranged parallel with the shore, but at its extremities, situated in the nearest foreground, it is seen that these lines of ridges are directed toward the sea, diminishing in number, losing their regularity, and finally mingling together and being drawn out into a little streamlet which gradually disappears. If we could study the other pool as readily, we should discover an absolutely similar disposition of the ripple marks at the bottom of it. It also terminates in a rill. The two together seen from farther off and higher up from the top of the cliffs (Fig. 9) present with perfect symmetry the appearance of a pair of French mustaches with long ends drawn down equally.

What has gone on here? It should not be imagined that hieroglyphics are more easy to decipher than these marks traced on the sand. Wherever the strand was so flat that the water could flow normally from the cliffs and toward the sea, the sandy grains, whatever might be the manner in which they were propelled, strike briskly against the waves, or the natural impulse of the tide. Whatever the inclination of the area on which they roll (in other words, whether on the lower beach as on the higher beach, as one can verify from the foregoing photograph), they are deposited in a uniform layer. They cannot follow the same course in a double depression. Those which at first, when the sea strikes the plain far from the foot of the cliffs, had not the least importance end by acquiring one a little before the receding tide completely abandons them. At this moment the layers of water which sweep the depression from side to side, rise swiftly to a certain height on the slope of the upper beach, but in returning all the water cannot again avoid the constantly growing obstacle which extends across its route on the progressively exposed plane of the lower beach. At the surface a part of this water still passes, but the greater portion, diverted by the knob of sand toward the middle of the pool, accumulates there seeking its level of equilibrium, and in order to find it flows out in a wavy course to the right and left toward the two extremities, where, with the aid of the last waves, it divides into a double stream, creating, in consequence, two small currents running in opposite directions parallel to the shore.

One learns from this the manner in which is formed, at this point, the deposit of sand grains carried by these currents running at right angles with the current of the tide, which brings them from the upper beach. Meeting in the pool water that possesses little force they lose their speed and are deposited. But, while they are falling to the bottom, the transverse current intervenes, turns them aside and arranges parallel with the shore this unstable, changeable mass, which is in course of formation rather than formed, and consists of these sandy particles, for the most part still suspended in the water.

Thus appear the parallel lines of ripple marks which reveal by their direction that of the secondary currents, and by their undulations the serpentine windings which are impressed on them by the vertical oscillations of the waves. Though very distinct where the divergence of the two lines of currents form an angle of 90 degrees, the ripple marks lose little by little their regularity at a distance, and in the same measure as the forces in operation become weakened. They end by disappearing altogether in the drain where the transverse current, definitely deflected toward the sea, loses itself in the current of the tide.

Thus is the phenomenon very simply explained. In every part of the lower beach where a current runs more or less nearly at right angles with the normal current of the ebb, their combined effects inscribe themselves in ripple marks on the sand.

We arrived at this conclusion on noting the appearance which the ripple marks present when they have acquired their definite form. More convincing than any argument is the reproduction here given of a photograph showing these currents, surprised while at work and depicted in the immobility of a hundredth of a second at the moment when, under their double action, little lines of shadow stamp upon the smooth surface of the sands the first outline of ripple marks. I sought for a long time to obtain this illustration, and though a difficult task, it was finally secured.

Let us suppose that at the moment of breaking on the shore, a wave happens to strike a rock presenting a surface at an angle of about 45 degrees. The wave, carried along by its own energy, washes this surface, and then falling down and turned aside by it, retreats to join the sea, in an elliptical course (Fig. 10).

The sandy particles which it carries, as in the pool previously mentioned, are urged forward in two directions, *OA* and *OB*, the one perpendicular to and the other parallel with the shore. Ripple marks should be formed there. This is confirmed by the accompanying instantaneous photograph (Fig. 11). A wave has broken under precisely these conditions. One can discern still the contour of the fringe of foam that it spreads out on the beach. Being violently thrown from left to right, it has already abandoned the left portion. The obliquity of its course is revealed, in part, at least, by the direction of the line of shadow, which, at the right, marks the elevation which it forms on mingling with the succeeding wave, which latter at this point has not itself undergone any deviation. Where the receding wave has passed are displayed the features of ripple marks.

In general, as we have established in the bottom of our little pool at Pouldu, ripple marks arrange themselves parallel with the line of the shore, under the predominating influence of the transverse current, which draws the sands toward the outlet. On the contrary, the direction of the ephemeral marks outlined here (Fig. 11) approach much more closely to a perpendicular than to a parallel with this line. The reason of this difference is very simple. It lies in the fact that this instantaneous photograph was taken on the upper beach. There only the action of the normal reflex current which levels the sand ordinarily exerts itself. It is owing to a quite special circumstance that accidentally the effects of the descending current were altered for a few seconds to a slight degree. The direction of the ridges formed express the relation between the two forces which acted together at this place.

But let us not make a point of this photographic document which was obtained with difficulty, and may doubtless appear insufficiently clear and convincing, moreover, as the jurists say, "*Testis unus testis nullus*," and as we have not been able to obtain any other evidence of this kind, we shall content ourselves with arguments derived from ripple marks which, like those of Pouldu, have acquired their definite form. In whatever place one observes them there are such numerous and harmonious evidences in favor of our theory that they appear to us irrefutable.

We now present an illustration of three conditions of the sand in the Bay of Somne (Fig. 12). The waters first descended vertically down the slope of the upper beach directly toward the spectator, then at a certain moment they ran obliquely to reach the rivulet at the right, between the piles of the wharf, that should direct them toward the sea. The first slope, where ordinarily the action of the receding water alone exerts itself, is leveled. The less-inclined slope of the intermediate area, on the contrary, is covered with ridges due to a double action, the preponderating one of the transverse current and the diminished action of the normal current.

Again, in Fig. 13, we have, seen from above, that marvelous whirlpool of Trieux, dominated by the chateau of Roche-Jagu and its park. Owing to an effect of shadow one can distinguish in this view all the details of the relief of the ground. They are significant. At the same time that the descending tide washes the elongated sand bank at the middle of the river from above downward water runs laterally to join it from the channel at the right and from a rivulet furrowed in the mud at the margin of the shore at the left. Ripple marks are formed at this place.

Let us now return to the great beach at Goulven, represented at the beginning of this article (Fig. 1). If one introduces this view between the following (Fig. 14) and that which we have given in Fig. 5, the accompanying panoramic view (Fig. 15) will be obtained. We see at the right the shore and the most distant point of the bay dominated by a picturesque rocky mass called "The Cathedral"; at the left, stretched across the bay, a series of high granite ledges which extend above the water. The waters have receded and leveled the slope of the sands accumulated around these knobs. But directed in consequence toward the middle of the bay they have been obliged, in order to get out, to seek two lateral outlets. They have taken the direction of *F* and *F'*. Do we not have here again, on an immense scale, our pool of Pouldu, with its two lateral outlets and its ridges parallel with one another and with the shore?

The similarity of the two illustrations will be better comprehended by turning again to Fig. 1 and examining very closely (with a magnifying glass, one might say) the smallest details of the landscape. The lines of ripple marks are drawn out over a long distance, but in reality they show at a number of points a lack of continuity. They appear to be composed of bars which follow one another irregularly, or do not stand in line at all. To summarize, this immense field of undulations may be divided into an infinity of pools similar to that of Pouldu and of banks much less important even than that of Trieux. They form a mosaic. This admirable design is effected by means of fragments and pieces, pools and banks of sand in juxtaposition, and separated by a series of parallel rivulets, some still full of water and others already completely dry, just as shown in the first illustration, where one may see at the right ridges becoming progressively deformed and losing themselves at the place where the two generating currents have taken a common direction.

The same spectacle presents itself within the bay as at its mouth. Everywhere, from whatever point we take up the question, we always arrive at the same conclusion. All these marks (with certain exceptions due to the movements of the ground, which, if we stop to study them, witness in favor of our theory) in their entirety are directed parallel to the shore toward a rapid creek formed on the right side of the bay by the retreat of the water which the sea every day carries to a marsh (Fig. 16) that occupies, between Plounéour-Trez and Goulven, the head of the bay. If our theory be correct, one ought from the existence and direction of these ridges to conclude that the waters of the bay do not retire in a direction perpendicular to the beach, but are diverted more or less obliquely to it and toward this outlet. This is what I have always noted. One day especially, when hidden in the thicket on a sandy bar of the swamp in pursuit of herons, I killed one of these birds. The tide was high and consequently close at hand, and the bird fell into the water. As I had just eaten, it was impossible to swim out in order to recover it, and I was obliged to abandon it. The tide being high, it floated past me in a tantalizing manner. It was my first heron! When the tide had receded a little, however, the bird floated away quickly and obliquely toward the right in the direction of the creek, the outlet of all the waters of the bay. When it had arrived there it passed quickly outward and in a few minutes was lost to sight. At the same time the existence of a transverse current combining its effects with those of the ebb was revealed to me, the formation of ripple marks was demonstrated, and their direction explained by the course which the bird had followed. I had lost the specimen, but not my time.

One can understand also that ripple marks are always found on the bar of a river, like that of the Belon, for example, which is bare during the spring tides. The mass of water which flows down from the ravine, striking against an obstacle in its path, is forced to turn laterally to seek toward the shore an easier passage; on the left, the side of the small bay of Kerfany, the real channel of the Belon; at the right, a small depression resulting from the washing out of the sands by the eddy in front of the rocks of the point of Riec.

We may now return to the furrows in the dry sand of the dunes, or in the snow on the mountains. It will be observed that whatever the agency, air or water, the process is always the same. The ripple marks are never formed on the surfaces exposed to the full current, but always in the gullies, or on the side of slopes over which the current of air descends obliquely. Their direction indicates the course of the current (Fig. 17).

On the contrary, where no transverse current intervenes ripple marks are lacking in the places in which one might have expected to find them. Our angle of the beach at Fort Bloqué (Fig. 6) is without them, because the peninsula which serves as an embankment to the fort prevents the access of all currents parallel with the shore, that of Coureau passing between the Lorient section of the mainland on the east, and the island of Groix. The ebb is produced there normally. The ripple marks appear solely at a point lower down and farther from the shore, outside the protected zone. Can it be said that they never form in the angle? Not at all. I have seen them sometimes, but when a strong wind from the west forces the water to the right, parallel with the shore into the depressions of the embankment.

I could multiply the examples indefinitely, accumulating the evidences, but this article would then be nothing more than an album of photographs. I shall not dwell on the evidence further, considering sufficiently demonstrated a fact that anyone, if I have failed to remove his doubt, can easily confirm on any beach. In concluding, I desire to return to two secondary points, but not unimportant ones, which, after mentioning incidentally, I put aside temporarily in order to first settle the principal questions. The secondary questions relate not to the mode of formation of ripple marks but to their location and the differences that are observed in their dimensions in the various places in which they appear.

Ripple marks, as I have observed, form only on the lower beach, and there again not in all places nor at all times. I will explain why none are seen in the photograph taken on the beach at Fort Bloqué. To account for their absence in this part of the bay of Goulven, shown in Fig. 5, which includes all portions of the ripple-mark field, it is necessary to take notice of a factor that has not as yet been mentioned. This is the nature of the bottom. Here we encounter a layer of mud and not of sand. It is not necessary to seek for any other reason why the ripple marks are absent. They do not form on muddy bottoms. Such bottoms, which are very compact because composed of very fine

particles, oppose to the attack of the tide a resistance all the more effective as their surface is viscous and gummy. The sea strikes them without finding more to take hold upon than the wind finds on a surface of water protected by a film of oil. A current may, however, if it be very violent, leave some trace of its passage, but indistinct and of little importance. In place of ripple marks one observes that kind of choppy appearance, like the coagulations in a semiclear soup, which one sees in Fig. 5. It is of interest to compare the effects produced by the same current under exactly the same conditions in two places near Lesconil, distant scarcely 100 meters from one another, in the one case on mud (Fig. 18) and in the second on sand (Fig. 7).

Between the mainland and the island of Oléron the rapid current of Maumusson produces on the coarse sands from the point of Menson to the St. Trojan landing, ripple marks of enormous size in the furrows of which on the days of the spring tide one spears sole, turbot, plaice, torpedoes, and gurnards. But beyond this landing there extends an immense field of mud divided into separate masses in front of St. Trojan, unfrequented and inaccessible from the harbor of this locality and stretching all along the island as far as Ors, Le Château, and beyond. The layer of mud, constantly accumulating by the accession of fragments of shell derived from the oyster beds, attains a thickness of from 60 centimeters to 1 meter and more.

In Fig. 19 is shown lying exposed to the sun at low tide the surface of this desert of mud and the marks which indicate the currents flowing from the Straits of Maumusson and Antioche. It is impossible to recognize a trace of ripple marks there, although the place is scarcely 200 meters from the point of Menson and its ripple marks, and is affected by the same current.

Ripple marks, then, do not occur in pure mud. They are only formed on the sand, of whatever purity it may be. Although very muddy, as especially in the same locality, on the beaches of Angoulins, the sands cover it very easily. The bank with ripple marks, which we have already noticed in Bretagne in the river Trieux, was of a muddy sand, as is evidenced by the bright reflection of the sunlight on its surface.

It may be asserted that these undulations are nowhere so fine and sharp as where the currents find in suspension in the water which they propel enough clay to cement the always crumbling sandy materials of these ephemeral structures. If the sand is very pure, the grains roll too easily on one another and are prevented from coming to rest on the sides of the furrow. Such ridges consequently have a wider base and proportionately less height than ripple marks of a smaller size formed on bottoms that are slightly muddy. If the sand is not only pure, but of very large grains, such as is encountered, for example, at Penmark, at Guilvinnec, and at Langoz, or again south of Concarneau from the point of Jument to that of Trévignon, then the ripple marks are formed with great difficulty. They occur here only under the influence of very strong currents and attain in this case very remarkable dimensions.

From this circumstance I am led to formulate the last of the observations that I shall present, to wit, their dimensions are always in direct relation to the force of the currents that form them. If in the bay of Goulven, after having taken the view No. 1, with the coast of Plouescat for the horizon line, I had made a half turn and had advanced 200 or 300 paces in a new direction toward Brignogan, I should have photographed ripple marks twice the size of those shown in Fig. 1. It is in this place that the creek that serves as the outlet of the marsh and bay passes through, much increased in breadth and lacking depth, though still rapid. During the whole time of the ebb, the entire strength of the current bears on this point, and the ridges on the coarse sands transported there reach an exceptional size.

In the same manner may be explained the dimensions of the ripple marks on the bar of the Belon. By itself the Belon does not exist as a river. Close to its mouth toward Riec and Moëlan, in the vicinity of Guilly, it is:

> A small brook, scarcely appearing to flow.
> A thirsty giant drinks it up at a breath.

But between the two resisting ledges of granite the ocean has furrowed in its direction landward a passage or fjord, at the outlet of which, between the points of Riec and Kerfany, this brook in the open sea takes on at the hour of the ebb the proportions and the force of an impetuous river. Its sound is considerable, and the depth of the channels furrowed in the sands of the bar measures its power, just as the size of the ripple marks formed opposite the point of Menson reveal the currents that flow around the island of Oléron.

To summarize, I shall formulate the following conclusions:

1. Ripple marks are due entirely to the action of water.
2. They are never formed on the upper beach nor on entirely muddy bottoms.
3. They appear on all parts of the lower beach, where, on the sandy bottom, a transverse current cuts across the normal current of the ebb.
4. They are aligned in the direction of the transverse current. Their current, if they deviate, expresses the relation of the two forces which are in action.
5. Their dimensions are a function of the nature of the bottom, the size of the grains of sand, and the velocity of the water.

The Antecedents of the Study of Character and Temperament*

Primitive Superstition and the Evolution of Physiology

THE strong practical interest in the sources and varieties of human powers and their proper direction and training, may be utilized in behalf of the retrospective aspects of the subject. The antecedents of "character and temperament" concern in the main the story of false and ambitious leads and venturesome solutions of the sources of human nature. However completely discredited, they belong to the irrevocable stages of our intellectual heritage, and show how uncertain has been the occupation of the psychological realm. The historical connection between the antecedents and present-day views is irregular; the succession of opinion is largely by replacement and outgrowth. None the less the points of connection are frequent with the body of knowledge which we draw upon so readily for the satisfaction of our systematized and rationalized inquiries.

The popular interest in human nature is itself an expression thereof. Actions are largely regulated as well as interpreted by psychological considerations; and these turn attention to the nature of the mind. The feeling of strong impulse, the sense of conflict between emotions as also between desire and sanctioned conduct, the search for motives, as well as the shrewdness of the battle of wits, and the reading of another's intentions shape psychological insight. "Know thyself" is an ancient precept—at once a moral injunction and an invitation to psychological study. The early contributions to the field to be surveyed came from the learning aptly called "the humanities," and reflected the insight of experience, directed by an unschooled but worldlywise analytical temper. Quite as science is glorified common sense, so is literature elevated common sentiment; either may fail to rise above a suggestive type of opinion or pleasing conjecture. The delineation of character springs from the impressionistic attitude toward the products of nature and the vicissitudes of fortune. It is animated by a fundamental interest in one's kind. It trains men to be practitioners, empirics in large measure, in the arts of human intercourse, and tends to establish man as the proper study of mankind.

The distinctive service of Greek thought was to launch the permanently engaging intellectual problems; to this rule the problem of character is no exception. It presents the two tendencies—the impressionistic and the analytic—in characteristic form. Theophrastus (370–288 B. C.), is the prototype of the impressionistic delineators, yet is not without an analytic strain. He sets forth his intentions thus: That although all Greece is of one

> clime and temperature of air, and Grecians in general bred and trained up after one fashion, should notwithstanding, in manners and behavior be so different and unlike. I therefore, O Polycles, having a long time observed the divers dispositions of men, having now lived ninety-nine (?) years, having conversed with all sorts of natures good and bad, and comparing them together; I took it my part to set down in this discourse their several fashions and manners of life. For I am of the opinion, my Polycles, that our children will prove the honester and better citizens if we shall leave them good precedents of imitation: that of good children they may prove better men.

The "Characters" of Theophrastus form a group of sketches of human foibles, holding the mirror up to nature, comprising the dissembler, the flatterer, the gossip, the toady, the fop, the miser, the superstitious, the mistrusting, the querulous, the bully, the coward, the stubborn, the pompous, the boor and the bore, the malaprop of either sex, the well-intentioned fool and the public-disregarding autocrat. This gallery of mental and moral shortcomings served as a model for distant ages. A group of delineations of character appeared in England in the seventeenth century; and the model was still suggestive when George Eliot chose the title for her "Impressions of Theophrastus Such." The modern delineations emphasize circumstance, the vocations and social stations, reflect a more varied, a more specialized, and a more complicated world. The "idle gallant," the "mere dull physician," the "upstart country knight," the "pot-poet," the "plodding student," the "downright scholar," as well as the "self-conceited man," the "vulgar-spirited man," the "too idly reserved man," and men of other dispositions are subjected to keen strictures in the "Microcosmography, or a Piece of the World Discovered in Essays and Characters," by John Earle (1628). Such portraitures of human peculiarities, gaged by their moral or social desirability as examples to be followed or avoided, form an attractive compendium for the interpretation of men and their ways. Their consideration, ranging from gossip to philosophy, supplies the common touch of nature that makes the world of every time and clime akin, and presents graphically for our psychological contemplation the outward issues of disposition as shaped by opportunity and circumstance.

This vein of character-mining failed to yield the native ore of disposition. The more fundamental problem was early recognized in the venerable doctrine of the temperaments as the alleged determinants of the original yet distinctive natures of men, and in the general notion that outward uncontrollable forces, such as climate, and directive ones, such as breeding and training, were responsible for the types of individuals and races—as duly indicated by Theophrastus. The doctrines of the school of Hippocrates (fifth century B. C.), formulated the Greek point of view. Its philosophical procedure followed that of Empedocles in the search for elements and in the explanation of manifold appearance as their variable combination. The elements of creation were regarded as fourfold: Air, fire, earth and water. These are distinctive by virtue of elemental qualities: namely, dry and moist, hot and cold, heavy and light, which by combination yield the qualities of the elements: fire as hot, dry and light; water as cold, moist and heavy, and so on. The fourfold elements of the body are the *humors* or fluids; the blood, the (yellow) bile, the phlegm, and the black bile. Subjected to the play of analogy and correspondence in the speculative manner then employed, *blood* becomes related to *air*, has the quality of being *warm* and *moist*; the season which it typifies is *Spring*, and its temperament is the *sanguine*. Its direct opposite is *earth*, which is *cold* and *dry*, finds its bodily correspondent in the *black bile* and its season in the *Fall* of the year; its temperament is the *melancholic*. Fire as *warm* and *dry* has special relations to *Summer*, is represented in the body by the *yellow bile*, and produces the fiery or *choleric* temperament; while water as *cold* and *moist* is allied to the *phlegm*, to the sluggish season of *Winter*, and to the languid temperament which we still, in deference to Hippocrates, call *phlegmatic*.

These views were held as much more than speculative possibilities; they were practically applied. Diseases were regarded as defects in the composition of the humors, to be counteracted by appropriate applications of heat and cold, or of dry and moist, to restore a favorable equilibrium. Winter was held to be the dangerous season for a temperament lacking in fire; the body must not be too full of humors nor yet be too dry and sapless. The several ages of man from childhood to senility, reflected the natural sequence of dominance of the several humors.

The doctrine of temperaments is historically important quite beyond any illumination which it affords. It is obvious that the philosophers of the school of Hippocrates had no means of ascertaining that cheerfulness was resident in the blood, laziness in the phlegm, testiness in the yellow bile, and low-spiritedness in the black bile; nor that any such fundamental vital basis was afforded by the "humors" thus distinguished. Their habits of mind inclined them to such an opinion; and their sense of plausibility was gratified (where we see only far-fetched and irrelevant analogy), by observing the hot, moist fluidity of blood and the damp, cold sluggishness of phlegm. The originators of the doctrine of temperaments were empirical psychologists, who observed that differences of mental disposition, like cheerfulness and testiness, were common and conspicuous traits of men. They were also medical practitioners with a fair knowledge of the body and its ills, and recognized that mental dispositions were intimately related to bodily condition. Their philosophical temper found satisfaction in connecting these two varieties of information through the doctrine of the temperaments.

The doctrine does not stand alone as such an attempt.

* By Prof. Joseph Jastrow, University of Wisconsin, in *The Popular Science Monthly*.

The "spirit" theory of disease has a like basis and purpose; it reaches from primitive medicine to Christian exorcism and beyond. The reference of epilepsy or other mental invasion to a foreign and malignant spirit is not unrelated to the notion of animal spirits coursing through the body and finding a local habitation in the ventricles—literally, breathing-spaces—of the brain. Again, the doctrine of signatures, in accordance with which red flowers were considered efficacious in the treatment of blood diseases and yellow ones in the treatment of jaundice, or "heart's-ease" was prescribed for heart trouble, and walnuts for mental disorders (by virtue of the resemblance of their outer shell to the skull and of their convoluted kernels to the brain), illustrate the force of native analogy in cruder practices.

When notions of this order, instead of being carried along as the folk-lore products of primitive thought, assume a systematic form, they become more fantastic in the analogies employed as well as more remote from a corrective common sense. Astrology is the most ambitious of such efforts in both design and scope of application. The three persistent motives in this world-wide and world-old expression—a composite of primitive culture, superstitious survivals, and pseudo-scientific elaboration—seem to be the cure of disease, the reading of character, the fore-knowledge of the future and in all, the control of fate. The motives combine. Astrology aims to determine the character as well as the careers of men, to predict their liability to disease and its issues, and to prescribe the set of disposition—making one of jovial temperament if the hour of birth showed favorable relations to Jupiter, or gloomy (saturnine), if Saturn ruled the critical moment. These and related notions and systems form a vast background of belief, continuously influencing the views of character and its sources. Whether the causes or the signs of dispositions were regarded as resident in the fluids of the body, or in the stars and planets, or in the detailed contours of the features of the face and head—as in the later physiognomy, itself a revival of classic and popular lore—or with more modern but no less fanciful elaboration, in the "bumps" of phrenology, or again in the creases of the hand upon which palmistry specializes, there appears in all a common practical motive in the control of fate through insight or revelation, and a common quasi-logical attempt to establish its basis by reading the secret of its conditioning—the insignia of its dominion. The logic of the procedure, as judged by our standards, is of the feeblest, but these standards are the issue of many generations of experience, each critically testing the conclusions, revising and enlarging the data, of its predecessors. The stress of practice, we must bear in mind, is insistent. Men will apply what knowledge they have; they can not await its perfection. Ideals and systems support the intercourse with reality, but they also express the progress attained in reading its meaning; the ideal "has always to grow in the real, and often to seek out its bed and board there in a very sorry way" (Carlyle).

The ancient and honorable place of the doctrine of the temperaments in the evolution of psychological knowledge warrants its further consideration. Most influential were the contributions of Galen (A. D. 130-200), who developed the views of Hippocrates and whose authority dominated the medical world for centuries. The doctrine became a classical heritage through its incorporation in the Galenic system of medicine. Its survival in the transfer of Greco-Roman science and tradition across the desert of unprogressive ages, with their uncertain and irregular caravans of learning, was due largely to its association with the "humoral" theory of disease. This remained a central as well as a controversial issue in medieval and renaissance medicine, and was effectively retired only by the complete transformation of physiological conceptions inaugurated by Harvey's discovery of the circulation of the blood (1628). Along with this decisive reform in knowledge and method there was established the clinical temper of the practice of medicine, which was as largely set by Sydenham (1624–1689), as were the experimental standards by Harvey, as similarly the anatomical prerequisite had been supplied by Vesalius (1514–1564). Cumulatively these advances served to cast off the spell of Galen and to install verification and observation in place of authority. As a herald of the new learning the philosopher John Locke, a friend of Sydenham's, wrote:

> You can not imagine how little observation, carefully made by a man not tied up to the four humors (Galen) or salt, sulphur, and mercury (Paracelsus), or to acid and alkali (Sylvius and Willis) which has of late prevailed, will carry a man in the curing of diseases, though very stubborn and dangerous; and that with very little and common things, and almost no medicine at all.

These considerations show to what extent practices kept alive systems precariously supported by principles. Symptoms such as fevers and chills, parching and perspiration, substantiated the hot and cold, the dry and moist as clinical realities. Remedies were prescribed to counteract them, diets were arranged according to degree of dryness and moisture. Even when the classic doctrines were finally discarded, it was only to be replaced by others which were developed in the same manner.[1]

It is fortunate that the older currents of thought, medical and otherwise, were summarized at the very period at which they were destined to retirement by Harvey's fundamental discovery. Burton's "Anatomy of Melancholy" is a collection of all the mystic, fantastic, engaging and (to our minds), incredible procedures of an ambitious science, suggestive of the waste-products of the mind. Burton anatomizes the humors, recognizing the four primary juices

> without which no living creature can be sustained; which four, though they be comprehended in the mass of the blood, yet have their several affections. . . . Blood is a hot, sweet, temperate, red humour, prepared in the meseraic veins, and made of the most temperate parts of the chylus in the liver whose office is to nourish the whole body, to give it strength and colour, being dispersed by the veins through every part of it. And from it spirits are first begotten in the heart, which afterwards by the arteries are communicated to the other parts.

and so on, with a like conjectural anatomy and acrobatic physiology for the other humors. Burton's appetite for the occult inevitably made him a believer in astrology. It is a fact that his horoscope is pictured on his tombstone, but it is presumably but a rumor that he assisted the fulfillment of the prediction of the time of his death by hanging himself. Burton's work is suggestive in view of the career of the doctrines which superseded the "temperaments" as practical exponents of character. It indicates the ready temptation for views of this nature to degenerate into vain pseudo-science, and under a common enthusiasm and prepossession to bring together in mutual tolerance diverse notions of like conjectural basis. Their common motive is a strong leaning toward the occult.

Alternatives in Case of a Dyestuff Famine

It is evident that any prolongation of the existing war increases the probabilities of a serious famine in artificial dyestuffs.

Responsible heads of textile works, who have studied the problem, find three outlets from the dilemma:

(1) The textile industries may be forced to put upon the market, to a large extent, goods that are undyed. This would be an unsatisfactory solution. The demand for such goods would certainly fall below the normal, and there would be a serious drop in prices.

(2) A return may be made temporarily to the use of natural dyestuffs. In some instances vegetable substitutes can be obtained with tolerable rapidity. This would be particularly the case with logwood. The output can be quickly increased and provision made for dyeing black on both cottons and woolens, although at the sacrifice of fastness. Fairly ample supplies of orchil can be secured at short notice and can be used for reds and browns in dyeing carpets and woolens generally. There would also be no great delay in obtaining a stock of yellow woods. Considerable time would be lost, however, before the coloring matters could be extracted and properly treated in order to develop desired strength and quality. In the case of indigo and madder several years would elapse before the needed stocks could be obtained. It would be scarcely possible to collect more than a fraction of the cochineal required for scarlets. The majority of tints now in common use could not be produced at all. Needless to say, there would be involved a revolution in the methods of dyeing.

(3) The attempt could be made to build up rapidly an American coal-tar dyestuff industry, self-contained and independent, based upon the use of American raw materials, and providing American consumers with all needed artificial dyestuffs. This would certainly demand some time, but would insure permanent freedom in the future from the dangers to which so many of our great industries are now exposed.

The desirability, and even urgency, of adopting the necessary measures for the creation of such a national industry have been advocated most earnestly by consumers of dyestuffs, by chemists, and by economists.—*Report of Bureau of Foreign and Domestic Commerce, U. S. Department of Commerce.*

[1] Medical theories and practise were reflected in popular lore. To recall the spirit of the ministrations it is sufficient to cite the venerable Chaucerian diagnosis made by Perteiote of Chanticlere's affrighting dream. This was ascribed to "the grete superfluite Of your reede colera, parde, Which causeth folk to dremen in her dremes Of arwes, and of frye with reede leemes, Right as the humour of malencolie Causeth iul many a man, in sleep, to crye, For fere of beres, or of boles blake, Or elles blake develes woln him take. Of othere humours couthe I telle also, That wirken many a man in slep full woo; But I wxol passe as lightly as I can. . . ." She then advises digestives and laxatives to purge him of "choler" and of "melancolie," though she bids him remember that he is "full colerick of complecioun" and should beware of the "sonne in his ascensioun." Amoung the artists, Albrecht Dürer reflected the current belief that temperament was responsible for the differences of men. He urged that artists should present the features and proportions suitable to the characters of their subjects. One of his ripest productions, commonly known as "The Four Apostles," also bore the title of "The Four Temperaments."—St. John representing the melancholic, St. Peter the phlegmatic, St. Paul the choleric, and St. Mark the sanguine.

The affiliation of "humors" and temperaments appears in the transferred use of the former term. The dramatic material of the age of Elizabeth with its free emphasis of personality, was typically staged in Ben Johnson's (1574–1637) "Eveny Man in His Humour" and "Every Man Out of His Humor." The following is from the induction to the latter.

"To give these ignorant well-spoken days some taste of their abuse of this word humour," the argument proceeds: "Why, *humour* as 'tis *ens*, we thus define it. To be a quality of air, or water, And in itself holds these two properties, Moisture, and fluxure: as, for demonstration, Pour water on this floor, 'twill wet and run: Likewise the air, forced through a horn, or trumpet, Flows instantly away, and leaves behind A kind of dew; and hence, we do conclude, That whatsoe'er hath fluxure, and humidity, As wanting power to contain itself, Is humour. So in every human body, the choler, melancholy, phlegm, and blood, By reason that they flow continually In some one part, and are not continent, Receive the name of Humours. Now thus far It may, by metaphor, apply itself Unto the general disposition: As when some one peculiar quality Doth so possess a man, that it doth draw All his affects, his spirits and his powers, In their confluctions, all to run one way, This may be truly said to be a humour."

SCIENTIFIC AMERICAN SUPPLEMENT

Founded 1876

NEW YORK, SATURDAY, SEPTEMBER 18th, 1915

Published weekly by Munn & Company, Incorporated

Charles Allen Munn, President; Frederick Converse Beach, Secretary; Orson D. Munn, Treasurer; all at 233 Broadway, New York

Entered at Post Office of New York, N. Y., as Second Class Matter

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The Scientific American Publications

Scientific American Supplement (established 1876) per year $5.00
Scientific American (established 1845) . . . . " 3.00

The combined subscription rates and rates to foreign countries, including Canada, will be furnished upon application

Remit by postal or express money order, bank draft or check

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Table of Contents

	PAGE
The Telegraph and Telephone in the German Army.—5 illustrations	177
Some Aspects of the Atomic Theory.—By Prof. Frederick Soddy	178
Calorific Value of Coal	179
War and the School.—By Our Berlin Correspondent.—3 illustrations	180
Measurement of the Distances of the Stars.—II	182
Two Historical Notes on Flotation	182
The Age of the Earth.—By F. A. Lindemann	183
New Weighing Balance	183
Coppering Iron and Steel	183
Motion-picture Magic.—By C. H. Claudy.—9 illustrations	184
The Movements of the Moon	185
The Theory of Cold Light.—By Wilder D. Bancroft	186
Your Lighting Bill for 1925.—By A. W. Deininger	187
Triplex Glass	187
Ripple Marks.—By Ch. Epry.—19 illustrations	188
The Antecendents of the Study of Character and Temperament	191
Alternatives in Case of a Dyestuff Famine	192

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177
178
179
180
182
183
183
183
184
189
186
187
188
191
192